SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.3 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Manufacturers: Subject to compliance with the requirements, provide products by one of the following:

1. Baldor (Basis of design)

B. Comply with NEMA MG 1 unless otherwise indicated.

C. Comply with IEEE 841 for severe-duty motors.

D. Motors to have three (3) year parts warranty.

E. Efficiency rating shall appear on nameplate and shall be not less than as follows:

MINIMUM NOMINAL FULL LOAD EFFICIENCY FOR 60 HZ NEMA GENERAL PURPOSE ELECTRIC MOTORS (SUBTYPE I) RATED 600 VOLTS OR LESS (RANDOM WOUND)						
	OPEN DRIP-PROOF MOTORS			TOTALLY ENCLOSED FAN-COOLED MOTORS		
HP	2 POLES 3600 RPM	4 POLES 1800 RPM	6 POLES 1200 RPM	2 POLES 3600 RPM	4 POLES 1800 RPM	6 POLES 1200 RPM
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	88.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8
250	95.0	95.8	95.4	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.5	95.8	95.8	96.2	95.8
450	95.8	96.2	96.2	95.8	96.2	95.8
500	98.5	96.2	96.2	95.8	96.2	95.8

MINIMUM NOMINAL FULL-LOAD EFFICIENCIES GENERAL PURPOSES ELECTRIC MOTORS (SUBTYPE II) AND ALL DESIGN B MOTORS GREATER THAN 200 HP								
	OPEN DRIP-PROOF MOTORS				TOTALLY ENCLOSED FAN-COOLED MOTORS			
HP	2 POLE 3600 RPM	4 POLE 1800 RPM	6 POLE 1200 RPM	8 POLE 900 RPM	2 POLE 3600 RPM	4 POLE 1800 RPM	6 POLE 1200 RPM	8 POLE 900 RPM
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	85.5	84..4	85.5	77.0
2	84.0	84.0	85.8	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0

5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	84.0
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	92.0	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

MINIMUM AVERAGE FULL LOAD EFFICIENCY POLYPHASE SMALL ELECTRIC MOTORS

	OPEN MOTORS		
HP	**2 POLES 3600 RPM**	**4 POLES 1800 RPM**	**6 POLES 1200 RPM**
0.25	65.6	69.5	67.5
0.33	69.5	73.4	71.4
0.50	73.4	78.2	75.3
0.75	76.8	81.1	81.7
1	77.0	83.5	82.5
1.5	84.0	86.5	83.8
2	85.5	86.5	N/A
3	85.5	86.9	N/A

MINIMUM AVERAGE FULL LOAD EFFICIENCY FOR CAPACITOR-START CAPACITOR-RUN AND CAPACITOR-START INDUCTION-RUN SMALL ELECTRIC MOTORS

	OPEN MOTORS		
HP	**2 POLES 3600 RPM**	**4 POLES 1800 RPM**	**6 POLES 1200 RPM**

0.25	66.6	68.5	62.2
0.33	70.5	72.4	66.6
0.50	72.4	76.2	76.2.
0.75	76.2	81.8	80.2
1	80.4	82.6	81.1
1.5	81.5	83.8	N/A
2	82.9	84.5	N/A
3	84.1	N/A	N/A

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

C. Motor Application: Provide the following enclosure types unless noted:

Environment/Location	Motor Enclosure Type
General Purpose	Open drip-proof with cast iron frame, TEFC with cast iron frame, or encapsulated
Outdoors, below grade or high humidity	TEFC with cast iron frame
Hazardous	Explosion-proof
Packaged Refrigeration Compressors	Hermetic or semi-hermetic

2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

C. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.

E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

2.6 SHAFT GROUNDING RINGS

A. Motors for use with Variable Speed Drives:

1. Shaft Grounding ring on NEMA Premium and inverter duty motors consisting of conductive microfibers and grounding path.

B. Shaft Grounding Kit for Field Installation:

1. Field applied shaft grounding ring for motors controlled by variable frequency drives designed to be installed by the contractor.

PART 3 - EXECUTION

3.1 MOTORS

A. Furnished by the equipment manufacturer and selected and installed for the intended use. Motors to be accessible for maintenance and, where applicable, belt adjustment.

3.2 SHAFT GROUNDING RINGS

A. Wire Shaft Grounding Kit on motors for use with variable frequency drives:

1. Ensure shaft grounding kit is installed on motor in accordance with manufacturer’s recommendations.
2. Shaft grounding ring (SGR) is bolted directly to the motor end bracket for installed with conductive epoxy to ensure ground connection from the SGR to the motor frame.

END OF SECTION 230513

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

a. Variable-air-volume systems.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TAB Specialist: An entity engaged to perform TAB Work.

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within 45 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 45 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 60 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. Certified TAB reports.

E. Sample report forms.

F. Instrument calibration reports, to include the following:

1. Instrument type and make.

2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

1.5 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity currently and for the duration of the project, certified by NEBB or AABC.

1. TAB Field Supervisor: Employee of the TAB contractor and currently certified by NEBB or AABC.
2. TAB Technician: Employee of the TAB contractor and individual who is currently certified by NEBB or AABC as a TAB technician.
3. TAB contractor shall maintain NEBB or AABC certification for the duration of the project.

B. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

C. TAB Report Forms: Use standard TAB contractor's forms approved by Engineer.

D. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

F. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.6 PROJECT CONDITIONS

A. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.7 COORDINATION

A. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

F. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

G. Examine test reports specified in individual system and equipment Sections.

H. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

I. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

J. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.

K. Examine automatic balancing valves. Remove balancing valve cartridge and flush clean prior to system balance and verification.

L. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

M. Examine system pumps to ensure absence of entrained air in the suction piping.

N. Examine operating safety interlocks and controls on HVAC equipment.

O. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance, smoke, and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" in this Section.

1. Comply with requirements in ASHRAE 62.1-2007, Section 7.2.2, "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Division 23 Section "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "HVAC Insulation."

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed as specified in Division 23 Section "Metal Ducts."

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer. Provide sheaves and belts as required to achieve indicated airflows.

1. Measure total airflow.

    a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

    a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
    b. Measure static pressure directly at the fan outlet or through the flexible connection.
    c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
    d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

    a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
6. Obtain approval from Architect for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.

    a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts. Provide sheaves and belts as required to achieve indicated airflows.

3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts

B. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.
2. Set terminal units and supply fan at full-airflow condition.
3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
4. Readjust fan airflow for final maximum readings.
5. Measure operating static pressure at the sensor that controls the supply fan if one is installed, and verify operation of the static-pressure controller.
6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

    a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.

8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

    a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

3.7 TOLERANCES

A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent.
2. Air Outlets and Inlets: Plus or minus 10 percent.
3. Heating-Water Flow Rate: Plus or minus 10 percent.
4. Cooling-Water Flow Rate: Plus or minus 10 percent.

3.8 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper

performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare weekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.9 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:

a. Settings for outdoor-, return-, and exhaust-air dampers.
b. Conditions of filters.
c. Cooling coil, wet- and dry-bulb conditions.
d. Face and bypass damper settings at coils.
e. Fan drive settings including settings and percentage of maximum pitch diameter.
f. Inlet vane settings for variable-air-volume systems.
g. Settings for supply-air, static-pressure controller.
h. Other system operating conditions that affect performance.

D. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Unit arrangement and class.
g. Discharge arrangement.
h. Sheave make, size in inches, and bore.
i. Center-to-center dimensions of sheave, and amount of adjustments in inches.
j. Number, make, and size of belts.
k. Number, type, and size of filters.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

a. Total air flow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Coil static-pressure differential in inches wg.
g. Outdoor airflow in cfm
h. Return airflow in cfm
i. Relief airflow in cfm
j. Outdoor-air damper position.
k. Return-air damper position.
l. Relief-air damper position.

4. Plate heat exchanger test report

a. Exhaust entering and leaving air temperature in deg F
b. Outside air and supply entering and leaving air temperature in deg F
c. Face and bypass damper position

E. Apparatus-Coil Test Reports:

1. Coil Data:

a. System identification.
b. Location.
c. Coil type.
d. Number of rows.
e. Fin spacing in fins per inch o.c.
f. Make and model number.
g. Face area in sq. ft..
h. Tube size in NPS.
i. Tube and fin materials.
j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.
d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
e. Entering-air, wet- and dry-bulb temperatures in deg F.
f. Leaving-air, wet- and dry-bulb temperatures in deg F.
g. Water flow rate in gpm.
h. Water pressure differential in feet of head or psig.
i. Entering-water temperature in deg F.
j. Leaving-water temperature in deg F.
k. Refrigerant expansion valve and refrigerant types.
l. Refrigerant suction pressure in psig.
m. Refrigerant suction temperature in deg F.

F. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches (mm), and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm (L/s).
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Suction static pressure in inches wg.

G. Round and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System and air-handling-unit number.
b. Location and zone.
c. Traverse air temperature in deg F.
d. Duct static pressure in inches wg.
e. Duct size in inches.
f. Duct area in sq. ft..
g. Indicated air flow rate in cfm.
h. Indicated velocity in fpm.
i. Actual air flow rate in cfm.
j. Actual average velocity in fpm.

H. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.
b. Location and zone.
c. Apparatus used for test.
d. Area served.
e. Make.
f. Number from system diagram.
g. Type and model number.
h. Size.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Air velocity in fpm.
c. Preliminary air flow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.

e. Final air flow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

I. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

a. System and air-handling-unit identification.
b. Location and zone.
c. Room or riser served.
d. Coil make and size.
e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Entering-water temperature in deg F.
c. Leaving-water temperature in deg F.
d. Water pressure drop in feet of head or psi.
e. Entering-air temperature in deg F.
f. Leaving-air temperature in deg f.

J. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.10 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
2. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.
b. Measure water flow of at least 5 percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
d. Verify that balancing devices are marked with final balance position.
e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Architect.
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Architect.
3. Architect shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

3.11 ADDITIONAL TESTS

A. Provide additional TAB visits as required to accommodate project scheduling and phasing.

B. Within one year of completing TAB, perform two additional TAB visits to verify that balanced conditions are being maintained throughout and to correct unusual conditions. Spacing between visits to be equally divided within the one year time frame and coordinated with the owner.

C. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 230713 - DUCT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. All Work shall comply with the requirements of the NYS Energy Code 2020, ASHRAE 90.1-2016, manufacturer's requirements for installation and these specifications. In the event of conflicts between these documents, the more stringent requirements shall met.

1.2 SUMMARY

A. Section includes insulating the following duct services:

1. Indoor, concealed and exposed air duct

B. Related Sections:

1. Division 23 Section "HVAC Equipment Insulation."
2. Division 23 Section "HVAC Piping Insulation."
3. Division 23 Section "Metal Ducts" for duct liners.
4. Division 23 Section "Nonmetal Ducts" for exterior ductwork.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

B. Detail application schedule of intended insulation type for each type of application.

C. Installation guide for each type of insulation specified. Highlight intended installation method.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control reports

B. Qualification Data: For qualified Installer.

C. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Duct Insulation Schedule, General" and "Ductwork Insulation Schedule" articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Fiberglass Blanket Insulation:

1. Insulation Blanket meeting ASTM C 553, Type II, ASTM C 1290, Type III, and ASTM C 1138.

2. 'K' Value of 0.27 at 75°F mean temperature. Maximum Service Temperature (Faced): 250°F.

3. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type I, II, III, IV, VIII or FSK conforming to ASTM C 1136 Type II, IV. Provide ASJ jacket for ductwork to be painted.

4. Installation: Maximum allowable compression is 25%.

5. Density: Minimum 1.0 PCF.

F. Fiberglass Board Insulation:

1. Insulation Board meeting ASTM C 612 Type IA, IB and II, ASTM C 795 and ASTM C 1138.

2. 'K' Value of 0.23 at 75°F mean temperature. Maximum Service Temperature: 450º F.

3. Vapor Retarder Jacket: ASJ conforming to ASTM C 1136 Type I, or FSK or conforming to ASTM C 1136 Type II, IV. Provide ASJ jacket for ductwork to be painted.

4. Concealed Areas: Minimum 3 lb./ft.3.

5. Exposed Areas: 6 lb./ft.3 minimum density for duct less than 8 ft. - 0 in. above finished floor or where indicated in these specifications or on the drawings.

G. Flexible Mineral Wool Blanket:

1. Mineral Wool bonded comply with ASTM C 553, Types I, II, and III, and ASTM C 1290 and ASTM C 1138.

2. ‘K’ value of 0.27 Btu-in/h-ft^2-F at a 75 deg F mean temperature. Maximum service temperature (faced): 250 deg F.

3. Vapor retarder jacket: FSK conforming to ASTMC 1136 Type II. Provide ASJ for ductwork to be painted.

4. Installation: Maximum allowable compression is 25%.

5. Density: Minimum 1.0 PCF.

H. Rigid Mineral Wool Board:

1. Mineral Wool complying with UL/ULC Classified per UL 723. Comply with ASTM C 612, type 1A, 1B, and ASTM C 1138.

2. 'K' value of 0.23 Btu-in/h-ft^2-F at a 75 deg F mean temperature. Maximum service temperature (faced): 450 deg F.

3. Vapor retarder jacket: ASJ conforming to ASTM C 1136 type I, II, III, IV, VIII, and FSK conforming to ASTM 1136 type II, IV. Provide ASJ for ductwork to be painted.

4. Concealed areas: Minimum 3 lb/ft^3.

5. Exposed areas: 6 lb/ft^3 minimum density for duct less than 8 ft above finished floor or where indicated in these specifications or on the drawings.

I. Acceptable Manufacturers:

1. Fiberglass and Mineral Wool: Knauf, John Manville, Owen-Corning, Certainteed.

2. Polyisocyanurate: Dow Trymer 2000XP, ByTherm.

3. Flexible Elastomeric: Armstrong, Rubatex International

4. Calcium Silicate: Industrial Insulation Group (ILG), John Manville, Owens-Corning

5. Removable Thermal Blanket: Insultech, Shannon, Irwin.

2.2 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Fiberglass Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

D. PVC Jacket Adhesive: Compatible with PVC jacket.

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Flexible Elastomeric Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. Products: Subject to compliance with requirements, provide one of the following:

   a. Aeroflex USA, Inc.; Aeroseal.
   b. Armacell LLC; Armaflex 520 Adhesive.
   c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller

2. Insulation finish shall be the insulation manufacturers recommended finish.
3. Adhesive shall be the insulation manufacturers recommended contract adhesives.
4. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
5. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Composition- synthetic rubber base with synthetic resins and fillers added

2.3 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.

2.4 SEALANTS

A. FSK and Metal Jacket Flashing Sealants:

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: Aluminum.

6. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. PVC Jacket Flashing Sealants:

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.
6. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.5 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

2.6 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, provide one of the following:

a. ABI, Ideal Tape Division; 428 AWF ASJ.
b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
c. Compac Corporation; 104 and 105.
d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.

2. Width: 3 inches.
3. Thickness: 11.5 mils
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, provide one of the following:

a. ABI, Ideal Tape Division; 428 AWF ASJ.
b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
c. Compac Corporation; 104 and 105.
d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ

2. Width: 3 inches
3. Thickness: 6.5 mils
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape

2.7 SECUREMENTS

A. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins:

a. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
b. Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch-diameter shank, length to suit depth of insulation indicated.

2. Cupped-Head, Capacitor-Discharge-Weld Pins:

a. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
b. Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch-diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

3. Insulation-Retaining Washers:

a. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
b. Self-locking washers formed from 0.016-inch- thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
c. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.

B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.

2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches O.C.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches O.C.

    a. For below ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

O. Insulate the tube bends and all exposed surfaces of duct coils operating in excess of 10 deg F differential from the ambient conditions.

3.4 PENETRATIONS

A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

1. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 07 Section "Penetration Firestopping

C. Insulation Installation at Floor Penetrations:

1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 07 Section "Penetration Firestopping."

3.5 INSTALLATION OF FIBERGLASS AND MINERAL-WOOL INSULATION

A. Blanket Insulation Installation on Ducts and Plenums: Secure with insulation pins.

1. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. Draw jacket tight and smooth.
    b. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
    c. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4 inches o.c.
    d. On rectangular duct sides with dimensions 24 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 18 inches O.C.
    e. On rectangular duct sides with dimensions larger than 24 inches, place pins 18 inches O.C. each way and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing. Provide pins and clip washers at 18" O.C. in the bottom of duct, minimum of 2 rows longitudinally.
    f. On round ductwork at 24" diameter and greater provide pins and clip washers at 18" O.C. in both directions from the horizontal centerline of duct downward.
    g. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    h. Do not over-compress insulation during installation.
    i. Impale insulation over pins and attach speed washers.
    j. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
    k. At all ductwork with external flanges, provide an 8" (min) piece of insulation wrapped around the duct, centered on the flange and securely taped.
    l. Sagging duct insulation will not be acceptable.
    m. Vapor retarders should overlap a minimum of two inches at all seams and be sealed with appropriate pressure sensitive tape. When applying pressure sensitive tapes, the tape must be firmly rubbed with the proper sealing tool to make sure the closure is secured. Follow tape manufacturers recommendations.
    n. For below ambient services, apply vapor-barrier mastic over staples.
    o. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
    p. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

2. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch O.C. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

    a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
    b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped

pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches

3. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
4. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
5. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
6. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches O.C.
7. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
8. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches O.C.

B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On all duct sides, space pins 12 inches O.C. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    b. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    c. Do not over compress insulation during installation.
    d. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
    e. Vapor retarders should overlap a minimum of two inches at all seams and be sealed with appropriate pressure sensitive tape. When applying pressure sensitive tapes, the tape must be firmly rubbed with the proper sealing tool to make sure the closure is secured. Follow tape manufacturers recommendations.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch O.C. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
6. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
7. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints
8. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
9. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches O.C. Tape and seal all ends and joints.
10. Vapor retarders should overlap a minimum of two inches at all seams and be sealed with appropriate pressure sensitive tape. When applying pressure sensitive tapes, the tape must be firmly rubbed with the proper sealing tool to make sure the closure is secured. Follow tape manufacturers recommendations.

3.6 FIELD-APPLIED JACKET INSTALLATION

A. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches O.C. and at end joints.

3.7 FINISHES

A. Exposed insulation shall have paintable jacket material: Paint jacket with paint system identified below and as specified in Division 09 painting Sections.

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a. Finish Coat Material: Interior, flat, latex-emulsion size.

B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

C. Do not field paint aluminum or stainless-steel jackets.

3.8 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location for each duct system defined in the "Duct Insulation Schedule, General" Article.

D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.9 DUCT INSULATION SCHEDULE, GENERAL

A. Items Not Insulated:

1. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
2. Factory-insulated flexible ducts.
3. Factory-insulated plenums and casings.
4. Flexible connectors.
5. Vibration-control devices.
6. Factory-insulated access panels and doors.
7. Exhaust ducts
8. Supply and return duct with an interior temperature difference to the exterior of the ductwork which does not exceed 15 deg F.

3.10 DUCTWORK INSULATION SCHEDULE

Service	**Insulation Material**	**Thickness**	**Remarks**
HVAC Supply	Within mechanical rooms or exposed at 8 feet or less above finished floor: Rigid fiberglass, [Mineral Wool] Concealed: Flexible fiberglass, [Mineral Wool]	1-1/2 in. 2 in.	Min. installed R value of 6 Min. installed R value of 6
Supply or Return ducts in cold attic spaces or other un-conditioned spaces	Flexible fiberglass, [Mineral Wool]	5 in	Min. installed R value of 12

Service	Insulation Material	Thickness	Remarks
Exhaust ducts in cold attic spaces or other unheated spaces	Flexible fiberglass, [Mineral Wool]	3 in	Min. installed R value of 8
Supply ducts, exposed within the conditioned space served and downstream of the reheat coil		Not Insulated	Does not include the associated supply ductwork within the Mechanical Room or supply duct to the conditioned space.
Interior ductwork indicated to be lined		Not Insulated	
Return-air ducts within heated building envelope		Not Insulated	
Neutral ventilation air supply (between 65°F and 80°F)		Not Insulated	
Outside air ducts and plenums, connections and mixing boxes	Rigid fiberglass, [Mineral Wool]	3 in.	Min. installed R value of 12 Provide neat fit at intake plenum
Exhaust, relief or vent ducts and plenums	Exposed: Rigid fiberglass, [Mineral Wool] Concealed: Flexible fiberglass, [Mineral Wool]	1-1/2 in. 2 in.	Min. installed R value of 8 Insulate 15 ft. from exterior opening and plenums

END OF SECTION 230713

SECTION 230800 - COMMISSIONING OF HVAC

1.1 GENERAL

1.2 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions.

1.3 SUMMARY

A. Section includes commissioning process requirements for HVAC&R systems, assemblies, and equipment.

B. Related Sections:

1. Mechanical sections
2. Electrical sections
3. Division 01 Section "General Commissioning Requirements" for general commissioning process requirements.

1.4 ALLOWANCES

A. Labor, instrumentation, tools, and equipment costs for technicians for the performance of commissioning testing are covered by the "Schedule of Allowances" Article in Division 01 Section "Allowances."

1.5 DEFINITIONS

A. The commissioning agent; the commissioning agent shall be as designated by the owner, architect or engineer. The commissioning agent shall represent the owner in matters relative to the commissioning procedures as defined in this and other related section of the contract documents.

1. The contractor shall be as defined in the general conditions and in the contract documents.
2. The owner shall be as defined in the general conditions and in the contract documents.
3. The architect/designer shall be as defined in the general conditions and in the contract documents.

B. Commissioning terms

1. Design intent: The designer intention is as defined by the architect as to the purpose of the specific complete system or any of the system components.

2. Commissioning procedures; Documenting, calibrating, checking, inspecting, starting, testing, verifying and training required to assure the proper operations of the mechanical and electrical systems defined in the contract documents.

a. Pre-commissioning: checklists, commissioning checklists, pre-start checklist, commissioning functional documentation, deviation reports, preliminary and final test reports completed by the contractor to assure the mechanical systems and electrical systems are completed in accordance with the contract documents, manufactures requirements and in compliance with the design intent.
b. Commissioning functional tests are test that are of more detail than the start up tests performed by the contractor and/or the manufacture at start up.
c. The commissioning procedure is a cooperative effort by the designer, installing contractor, manufacture and the commissioning agent to ensure that mechanical, electrical, and control equipment, systems and components meet the design intent and to document the systems operation and compliance to the design intent.
d. The commissioning process includes the contractors' functions of start up, testing, balancing, calibration and set up of controls, training by the contractor.
e. The commissioning procedure testing and monitoring may include specific testing, trending and logging of the systems and /or components.
f. The contractor representative is an authorized contractor representative that shall be assigned as a qualified skilled technician to assist in the commissioning procedures.

3. Skilled technicians:

a. Personnel with specific expert knowledge of the system, components and/or control of the mechanical or electrical elements of the commissioned systems.
b. The skilled technician shall be qualified and have all tools required for commissioning the elements of the systems.
c. The skilled technician shall demonstrate a willingness and attitude of cooperation. The technician may be removed from the process at the request of the designer. The contract must replace the technician in this event with a technician meeting the above requirements.

4. Seasonal commissioning:

a. Seasonal commissioning pertains to testing under full load conditions during peak heating and peak cooling seasons, as well as part load conditions.
b. Initial commissioning tests will be done as soon as contract work is completed, regardless of season.
c. Subsequent commissioning tests will be undertaken as soon as practical to verify performance during the two seasons (peak heating, peak cooling or part load) not covered in initial testing.
d. Individual mechanical and electrical systems specifications indicate which systems require seasonal testing.

C. Commissioning team

1. Each contractor will designate one person, responsible for representing that facet of the project, to be on the Commissioning team. This person shall be the same person that is the lead person for installing and/or supervising the work of the trade being represented.
2. The commissioning team shall consist of the Owner, Commissioning Agent, Construction Manager, Mechanical Contractor, Electrical Contractor, General Contractor, Mechanical Contractor and sub contractors, Electrical Contractor and sub contractors, Test and Balance Contractor, Temperature Controls Contractor and the Engineer.

1.6 COMMISSIONING DUTIES

A. Duties of Architect:

1. Submit copy of the Design Intent Data to Owner, and review with Owner for acceptability.
2. Incorporate Design Intent data into bid and contract documents for contractor pricing and performance.
3. Prepare Commissioning Procedures for each the system based on actual system configuration.
4. Incorporate Commissioning Procedures into bid and contract documents for contractor pricing and performance.
5. Develop an integrated commissioning schedule with input from the contractor and representatives of all the installers.
6. Not authorize commissioning tests until each system is complete, including start-up procedures.
7. Coordinate communications related to commissioning by receiving and distributing submittal reviews, deficiency notices, and test results.
8. Identify problems; notify responsible parties, and direct actions required to correct deficiencies in EEM equipment and systems.
9. Remove Energy Efficiency Measures disputes by performing research to determine the scope of the dispute, and informing the involved parties on the possible solutions to the dispute.
10. Notify the Contractor if Contractor-initiated system changes have been made that alter the commissioning process.
11. Determine the acceptance procedures for each item of the equipment and system. The criteria for acceptance of the equipment and systems will closely follow the test outline in each Section specifying the equipment.
12. Submit the final commissioning report including al submittals and test results for each to the Utility and Owner. Commissioning Report shall be included in Part 5 of each section of the Closeout Manual.
13. Recommend final acceptance of contractor's work to the Owner when commissioning tests have been successfully completed.

B. Duties of Contractor:

1. Provide Commissioning Agent with access to the building and the work.
2. Provide input (in coordination with the installers) to the designer to develop an integrated commissioning schedule.

3. Coordinate work with commissioning work.
4. Ensure commissioning tasks and deliveries are performed in accordance with the Commissioning Schedule and Contract Documents.
5. Provide training to the Owner relative to the equipment components and the overall operation of the entire systems

C. Duties of Equipment and Systems Installers:

1. Review and approve Commissioning Procedures.

    a. Review is confined to ensuring test procedures are executable, will not damage equipment or systems, and will not affect warranties.

b. Review pre-commissioning checklists and functional performance test plans and data sheets for capability of verifying that the equipment and systems meet the Design Intent.
c. Provide assistance in functional performance testing and test and balancing, i.e. the TC contractor shall open all the vav boxes to test the unit at 100% speed so that the air flow measuring stations can be accurately calibrated.
d. Consult with equipment and systems manufacturers as required to verify that tests will not damage equipment and systems.
e. If installer deems it necessary for protecting equipment, they shall forward these documents to the appropriate manufacturer's representatives for review and editing.

2. Provide Skilled Technicians for execution of commissioning procedures including seasonal testing required after initial commissioning when required by Contract Documents.
3. Participate in resolution of disputes related to commissioning.
4. Provide qualified personnel for correction of deficiencies.
5. Train Owner's maintenance personnel in operation and maintenance of equipment and systems.
6. Submit operation and maintenance and as-built drawings for equipment and systems to Designer.
7. Installers shall cooperate with other Installers on commissioning Work that requires participation of multiple Installers.
8. Provide input (in coordination with the Contractor and other installers) to the Architect to develop an integrated commissioning schedule.
9. Commissioning does not relieve Installers from participating in the review process not diminish the Installer's role and obligations to complete other Work as required by Contacts Documents.

D. Duties of Commissioning Agent

1. Engage Commissioning Team

a. The Commissioning Team assists in planning, reviewing and coordination of commissioning activities with all disciplines involved in the building project. The Commissioning Team shall include the following members at a minimum. Contractors will not join the team until they are selected through the normal procurement process.

i) Commissioning Leader
ii) Facility Operations Manager (FOM)
iii) Project Manager
iv) Designers
v) Contractors
vi) Energy Modeler (if energy modeling is part of the project)
vii) Guideline Leader

2. The Commissioning Leader facilitates and coordinates the efforts of the commissioning team. For Design and Construction Commissioning, the commissioning leader shall have a distinct role from the design team but may be employed within a firm providing design services. The Facility Operations Manager is accountable for facility performance during ongoing occupancy and will manage or perform ongoing operations and maintenance following construction. This person is available to participate throughout the design and construction process for continuity into final operation.
3. Coordination of Owner's Project Requirements (as required by guideline P.1A)
   The Owner's Project Requirements (OPR) shall quantify functional performance expectations and parameters for each system to be commissioned. The OPR provides the common understanding that focuses design, construction, and commissioning activities on the desired outcome. The OPR shall be written in objective and measurable terms. Quantify parameters such as space temperatures, humidity levels, lighting levels, sound levels, and ventilation rates when applied to the conditioned building spaces. The OPR shall be updated every time the owner accepts an alternate requirement or performance criteria – due to owner desires, schedule, or budget. This might occur through normal design evolution, value engineering, change orders, or other supplemental instructions during construction.
   The OPR shall include an updated SB 2030 Energy and Carbon Standard for the project related to Guidelines E.1 and renewable energy requirements under E.2 and updated as the program and the project are refined. During the Correction Period and On-Going Operations, the OPR helps the owner/operators understand the requirements of the owner. It also provides the benchmark for maintenance, repair, and replacement decisions
4. Coordination with Basis of Design (as required by guideline P.1C)
   The Basis of Design (BOD) is a narrative description of how the systems will be designed in order to achieve the Owner's Project Requirement acceptance criteria.
5. Commissioning Design Review
   At least once during each of the Design, Final Design, review the design progress against the goals of the Owners Project Requirements. Commissioning Design Review comments shall be documented in writing and responses prepared by the appropriate designers
6. Coordinate and direct the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
7. Coordinate the commissioning work with the contractor and construction manager, to ensure that commissioning activities are being incorporated into the master schedule.
8. Plan and conduct commissioning meetings as needed and distribute minutes.
9. Performance Check: Commissioning Team shall review design as documented to verify that it meets the physical outcomes and operational performance defined at that phase. Performance areas include, but are not limited to:

   a. Owner's Project Requirements acceptance criteria for all required and additional pursued Guidelines.
   b. Requirements for specific operational scenarios of the building.

10. Measurability/Testability Check: Commissioning Team shall review design as documented to verify that it meets criteria for testing and verification of performance for Design and Construction Commissioning as well as Operations Commissioning monitoring during Ongoing Occupancy. Performance areas include, but are not limited to:

a. Measurements and testing required during all phases of Design and Construction Commissioning.
b. Measurement, monitoring, and control of energy, water, indoor environmental quality during ongoing occupancy.

11. Coordinate with Operations Commissioning and Energy Efficient Operations Manual Cooperate with the Operations Commissioning Team by incorporating design features required to perform Operations Commissioning. Refer to and coordinate with the completion of Guideline P.2A: SB 2030 Energy Efficient Operations Manual process.
12. List of I/O Data Points

    a. Submit a list of input and output (I/O) data points or sequence of operations as part of outcome documentation before the completion of the Final Design Phase. These shall be submitted for all computer-based control systems, e.g., HVAC, lighting controls which have programmable control logic.

13. Provide Cx Criteria & Scope for Construction Documents

    a. Provide a commissioning specification section for Division 1 of the project manual. The commissioning specification shall define and elaborate on the contractor's responsibilities as defined in the Commissioning Plan. Incorporate the Commissioning Plan into the contract documents by reference in order to communicate the context of the commissioning specification and information regarding other team member responsibilities.

14. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures. Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
15. Coordinate and direct commissioning activities.
16. Review normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
17. Review requests for information and change orders for impact on commissioning and owner's objectives.
18. Review coordination drawings to ensure that trades are making a reasonable effort to coordinate.
19. Write and distribute construction checklists for commissioned equipment.
20. Develop an enhanced start-up and initial systems checkout plan with contractors for selected equipment.
21. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
22. Perform the following pre-functional tasks:

    a. Witness HVAC piping pressure test and flushing, enough to be confident that proper procedures were followed. Include testing documentation in the Commissioning Record.
    b. Witness any ductwork testing and cleaning enough to be confident that proper procedures were followed. Include documentation in the Commissioning Record.

c. Document construction checklist completion by reviewing completed construction checklists and by selected site observation.
d. Document systems startup by reviewing start-up reports and by selected site observation.
e. Approve air and water systems balancing by spot testing and by reviewing completed reports and by selected site observation.

23. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This will include manual functional testing, energy management control system trending and may include stand-alone datalogger monitoring.
24. Coordinate, witness and document manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved. The functional testing shall include operating the system and components through each of the written sequences of operation, and other significant modes and sequences, including startup, shutdown, unoccupied mode, manual mode, staging, miscellaneous alarms, power failure, security alarm when impacted and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during construction check listing by the installing contractors and spot-checked by the commissioning provider during functional testing. Analyze functional performance trend logs and monitoring data to verify performance. a. Tests on respective HVAC equipment shall be executed, if possible, during both the heating and cooling season. However, some overwriting of control values to simulate conditions shall be allowed. Functional testing shall be done using conventional manual methods, control system trend logs, and read-outs or stand-alone dataloggers, to provide a high level of confidence in proper system function, as deemed appropriate by the commissioning provider and the Owner.
25. Prepare test plans for, assist with execution of, and document tests of commissioned equipment overseen by regulatory authorities and ensure that such tests meet the testing rigor desired by the Owner.
26. Maintain a master issues log and a separate record of functional testing. Report all issues as they occur directly to the Owner's Representative. Provide directly to the Owner's Representative written progress reports and test results with recommended actions.
27. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
28. Oversee and review the training of the Owner's operating personnel prior to construction completion and system acceptance by the owner.

    a. Oversee the videotaping of this training.
    b. Review the creation of a classroom "owner's manual" that is to be kept in the classroom.
    c. Review the preparation of the O&M manuals for commissioned equipment.

29. Compile a Commissioning Record, which shall include:

    a. A brief summary report that includes a list of participants and roles, brief building description, overview of commissioning and testing scope, and a general description of testing and verification methods. For each piece of commissioned equipment, the report should contain the disposition of the commissioning provider regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:

1) Equipment meeting the equipment specifications,
2) Equipment installation,
3) Functional performance and efficiency,
4) Equipment documentation, and
5) Operator training.

30. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented.
31. Also included in the Commissioning Record shall be the issues log, commissioning plan, progress reports, submittal and O&M manual reviews, training record, test schedules, construction checklists, start-up reports, functional tests, and trend log analysis.
32. Compile a Systems Manual that consists of the following and at least the parts listed under ASHRAE 202-2013 Part 14.2.3: Owner's Project Requirements (by owner); Design Narrative and Basis of Design (by designer); Performance Metrics, if completed during design; space and use descriptions, single line drawings and schematics for major systems (by designer); control drawings, sequences of control (by contractor); and a table of all setpoints and implications when changing them, schedules, instructions for operation of each piece of equipment for emergencies, seasonal adjustment, startup and shutdown, instructions for energy savings operations and descriptions of the energy savings strategies in the facility, recommendations for recommissioning frequency by equipment type, energy tracking recommendations, and recommended standard trend logs with a brief description of what to look for in them (all by commissioning leader).
33. Deferred Verification
Some of the system functional performance test procedures will not be practical or meaningful to complete prior to the Correction Period. This may be due to construction phasing, climate or other constraints. Those test procedures shall be completed at the earliest appropriate time, and the results of the tests shall be reported to the Owner and Project team. It shall be expected that deficiencies identified as part of this deferred testing executed after the Correction Period will be resolved by the project team as if they had been identified prior to the end of the Correction Period.
34. Warranty Period

    a. Coordinate and supervise required opposite season or deferred testing and deficiency corrections and provide the final testing documentation for the Commissioning Record and O&M manuals.
    b. Return to the site at 10 months into the 12-month warranty period as scheduled by the Owner's Representative, and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have with operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.

E. Duties of all parties

1. Attend all commissioning scope meetings and commissioning team meetings. These will take place on an every other week schedule unless progress of the project dictates otherwise.

1.7 TEST EQUIPMENT

A. Test Equipment:

1. Contractor or installer shall furnish industry standard test equipment for performing tests.

B. Proprietary Test Equipment:

1. Contractor or Installer shall provide proprietary test equipment required by equipment manufacturer.
2. The contractor shall demonstrate test equipment use and assist in the commissioning process.
3. The contractor shall provide instrument calibration and maintain test equipment a recommended by manufacturer.

1.8 EXECUTION

1.9 TESTING PREPARATION - COMMISSIONING PROCEDURES AT THE SITE

A. Coordination of Tests:

1. The commissioning agent shall develop an integrated Commissioning Schedule with input from the Contractor and all installers.
2. Contractor shall coordinate schedules of all installer representatives, and enforce participation in commissioning tests according to the Commissioning Schedule.
3. An installer shall not test work by another installer.
4. When testing systems that include work by multiple installers, representatives of all effected installers must be present.
5. Installer shall complete commissioning checklists during equipment and system start-up.
6. Commissioning tests of systems may proceed prior to final completion of systems to expedite the testing progress if approved by Designer.
7. Do not initiate functional performance testing for equipment or systems in advance of their start-up and checkout by all affected Installers for that equipment or system.
8. Test and record Mechanical, Control, and Electrical systems through each mode of operation using Commissioning procedures.

B. Test Acceptance Criteria:

1. The criteria for acceptance of each test is only if that test results will be in accordance with and demonstrate the Design Intent.
2. Input will be sought when necessary from the Designer to determine if test results indicate compliance with the Design Intent.
3. The Designer will recommend acceptance or rejection of work based on the test results.

C. Resolution of Deficiencies:

1. Designer will review performance tests and notify the Contractor indicating the nature of deficiencies and steps to be taken.
2. Installer shall adjust defective equipment and systems to meet performance requirements under varying loads.
3. Contractor shall set the date for completion of corrective activities. This date shall be within fifteen (15) working days of the date the deficiency report was generated.

    a. The correction of issues described in the deficiency report must be signed by the party responsible for correcting the deficiency, and returned to the Commissioning Agent within the 15 day period.

4. If the date for completion of corrective work passes without resolution of deficiencies, Owner reserves the right to obtain supplementary services and equipment to correct the problem as indicated in the General Conditions.
5. Commissioning procedures shall be aborted and considered failed, if any commissioning team member, for whom participation is scheduled, is not present for the test.

    a. This will not be considered a failure if the test is rescheduled 48 hours (minimum) in advance of the scheduled testing.

6. Installer shall perform additional commissioning procedures until the required system performance is obtained.

D. Re-checking and Re-testing Charges:

1. In the event of a second failure of a commissioning procedure for equipment and systems, the Contractor will be assessed charges by the Designer, and other commissioning review parties to do additional testing on the site for re-testing equipment and systems.
2. Charges will be based on each party's expenses, including normal hourly billing rates, time for re-testing, travel time, travel expenses, and per diem, if required.

1.10 O&M MANUAL

1. Ensure that Operation and Maintenance Manuals are accurate and complete. Forward this document to the Owner.

1.11 PRE-FUNCTIONAL START-UP

A. Start-up reports shall be completed by qualified installers responsible for installing the piece of equipment.
B. The Contractor shall be responsible for performing any additional manufacturers or local codes officials' start-up requirements at no additional cost to the Owner.
C. The Contractor is responsible for ensuring a factory-authorized service representative is present for star-up procedures where such representation is mandated to attend start-up.
D. The Contractor shall verify the equipment checklist is completed before operating the equipment.
E. The completed start-up checklists shall be returned to the Commissioning Agent.
F. The equipment requiring prefunctional testing include, but are not limited to, the following:

1. Chillers
2. Boilers
3. Pumps
4. Air Handling Units
5. Ventilation Fans
6. VFD's
7. Air Terminal Units
8. Ductwork/Pipe Insulation
9. Pipework
10. Temperature Control
11. Temperature/Humidity Sensors
12. Pressure Sensors and Controllers
13. Sequence of Operation
14. Airflow Stations
15. Damper/Valve Actuators
16. Plumbing Equipment
17. Plumbing Piping Systems
18. Fire Pump
19. Normal Power Electrical Systems
20. Lighting Control/Daylighting Systems
21. Emergency Power Systems
22. Fire/Life Safety Systems
23. Security Systems
24. Communication Systems (including voice, data,PA)
25. Renewable and Alternative Energy Technologies
26. Waste Heat Recovery Systems
27. I.A.Q. Pre-Occupancy – Office
28. I.A.Q. Post-Occupancy - Office

G. Functional Start-Up

1. The equipment requiring functional testing may include all components of the mechanical system and is at the discretion of the Owner and Commissioning Agent. The minimum required shall be all components of the following:

    a. HVAC systems

END OF SECTION 230800

SECTION 230993 – SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. Related Sections include the following:

1. Division 23 Section "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

1.4 AIR HANDLING EQUIPMENT SEQUENCES

A. Package Rooftop Units (RTU-1 thru RTU-3)

1. General:

a. Variable volume system with supply fan, packaged DX heating and cooling, and economizer cycle.
b. The DX heating and cooling system shall be capable of modulating capacity.
c. The RTUs shall be controlled during the occupied/unoccupied modes via the local controller, through an owner directed time schedule.
d. All control set points noted in this sequence shall be user adjustable and shall be tuned during system start up and commissioning for proper system operation.

2. Unoccupied:

a. Throughout the unoccupied period, the economizer damper shall modulate position to 100% return air, 0% outside air.
b. When the space temperature is between the unoccupied heating and cooling set points, the supply fan, heating and cooling shall be disabled.
c. On call for cooling, the supply fan shall be enabled. The unit shall switch to occupied mode with minimum outdoor air for economizer operation at zero. Once space temperature falls 2°F below the unoccupied cooling set point, the unit shall enter unoccupied shutdown.

d. On call for heating, the unit shall be enabled. The leaving air temperature set point shall be set to 55°F. The unit shall return to unoccupied shutdown when the space temperature rises 2°F above the unoccupied heating set point.
e. Unoccupied Schedule: Monday – Friday 5:00 p.m. – 7:00 a.m. Saturday, Sunday and Holidays.
    1) Heating set point: 62°F
    2) Cooling set point: 82°F

3. Occupied (adj.):

    a. Occupied Schedule: Monday-Friday 7:00 a.m. – 5:00 p.m.
    b. Fan shall be on.
    c. Heating set point: 70°F
    d. Cooling set point: 75°F

4. Start-up:

    a. When initiated by manual command through the local controller, the supply fan shall be enabled. After proof of operation, the PID loops for the cooling, heating section, and economizer shall be enabled.

5. Optimal Stop:

    a. As the system approaches the scheduled unoccupied period, the local controller shall calculate the optimal stop time of the heating/cooling components based on the zone's occupied heating/cooling set point, the current zone temperature, the outdoor air temperature, and a mass/capacity factor. The mass factor shall be tuned by the local controller. Optimal stop shall be calculated such that no zone will drift more than 3°F (adj.) from set point before the start of the scheduled unoccupied period. During optimal stop, the supply fan, and economizer damper shall continue to operate to ventilate the zone(s) per their specified occupied operating sequence.

6. Shutdown:

    a. When initiated by manual command through the local controller system or triggered by a safety device, the unit shall shut down. Heating/cooling shall be disabled. After a time delay of 180 seconds (adj.), the fan shall be disabled. After a programmable time, delay (initially 30 seconds) the economizer dampers shall position to 100% return air.

7. Optimum Start:

    a. Warm-up Mode:

        1) The local controller shall calculate the required warm-up time based on the zone's occupied heating set point, the current zone temperature, the outdoor air temperature, and a mass/capacity factor. The mass factor shall be tuned by the local controller. Warm-up mode shall no earlier than 1 hour before the scheduled start of the occupied period and shall end at the scheduled occupied start hour.

2) The discharge air temperature shall be set to 55°F, DX heating coil shall be controlled in sequence, to maintain a 55°F leaving air temperature. The re-heat coil discharge temperature shall increase the air temperature from 55 to 90°F until such time as the space temperature is equal to the occupied heating space temperature set point, at which time operation will be restored to automatic.

b. Cool-down Mode:

1) The local controller shall calculate the required cool-down time based on the zone's occupied cooling set point, the current zone temperature, the outdoor air temperature, and the mass/capacity factor. The mass factor shall be tuned by the local controller. Cool-down mode shall start no earlier than 1 hour before the scheduled start of the occupied period, and shall end at the scheduled occupied start hour.
2) The leaving air temperature set point shall be 55°F, and the economizer and DX cooling coil shall be controlled in sequence, subject to economizer lockout control, to maintain a 55°F leaving air temperature.
3) Upon completion of the cool-down cycle, the discharge air temperature set point shall revert to the calculated leaving air temperature set point per cooling operation of this sequence.

8. Cooling Operation:

a. Subject to startup and shutdown sequences and outdoor air lockout temperature, the cooling coil shall enable upon call for cooling from the discharge air temperature sensor. Cooling shall stage to maintain the space temperature.
b. During economizer operation, DX cooling operation shall not be enabled unless the economizer is at > 95%, and shall operate in sequence with the economizer as trim capacity to maintain calculated leaving air temperature set point.
c. The cooling system controls shall modulate the compressor and the hot gas bypass circuit to dehumidify the air without overcooling the space.

9. Ventilation Control (RTU-3):

a. CO_2 sensor, to be located on the wall in the associated space served by the unit.
b. DDC system shall continuously monitor the space CO_2 level. If the reading of the sensor is below 1200 PPM (adj.), the unit's outside air damper shall be positioned to supply the Minimum DCV OA Flow Rate (CFM) per the schedule.

c. If the reading of the CO_2 sensors exceeds 1200 PPM (adj.), the outside air damper shall open from Minimum DCV OA Flow Rate (CFM) to the Maximum OA Flow Rate (CFM) at a rate of 1% damper position per 3 minutes until the CO_2 sensor reads below 900 PPM (adj.). Maximum OA Flow Rate (CFM) shall be per schedule.

d. If the reading of the CO_2 sensor reads below 1100 PPM (adj.) and the OA reading is above the Minimum DCV OA Flow Rate (CFM) position, the damper shall close at a rate of 1% damper position per 3 minutes until the CO_2 sensor reads above 1200 PPM (adj.).

10. Economizer Operation:

    a. The local controller shall perform an enthalpy calculation to determine when it is more energy efficient to use outside air for cooling. The local controller shall continually monitor the return air enthalpy, constantly comparing it to the outdoor air enthalpy. Based on the data and the enthalpy calculation the local controller shall modulate the economizer damper to achieve mixed air temperature setpoint.
    b. When the outside air enthalpy is greater than the return air enthalpy (1.5 btu/lb. deadband), the economizer damper shall return to minimum position. When the mixed air temperature falls below setpoint 55 degrees F (adj.) the economizer damper shall go to minimum position. If cooling is required, but the return air temperature is lower than the outdoor air temperature, the economizer damper shall go to their minimum position. If the return air temperature is below an operator definable limit, then a warm-up cycle shall be initiated forcing the economizer damper to economizer damper to 100% recirculation air. When return air temperature increases above the limit, plus a definable differential, then the warm-up cycle shall be terminated.
    c. Economizer shall have a high limit shut off at 75ºF outdoor air temperature.
    d. Whenever the economizer is locked out due to outdoor air conditions or there not a command for economizer cooling, the economizer shall modulate for calculated minimum ventilation air flow.
    e. Whenever the economizer is operating, at no time shall the outside airflow rate as measured by the outdoor air flow station be allowed to drop below the calculated minimum ventilation rate.

11. Heating Operation:

    a. Heating, cooling/economizer operation shall be controlled such that no overlap between heating and cooling operation takes place.
    b. On call for heat, the discharge air temperature shall be set to 55°F, DX heating coil shall be controlled in sequence, to maintain a 55°F leaving air temperature. The re-heat coil discharge temperature shall modulate the air temperature from 55 toward 90°F until such time as the space temperature is equal to the occupied heating space temperature set point, at which time operation will be restored to automatic.

B. Variable Air Volume Air Terminal Units (VAV)

1. Terminal VAV Box, Cooling Only Control

   The local control system shall modulate variable volume damper in response to space temperature sensor fluctuation. When the space temperature exceeds the setpoint, the variable volume damper shall modulate open. As the temperature falls the damper shall modulate to minimum position. A "High/Low" position limit may be implemented to limit the minimum and maximum air flow.

2. Terminal VAV Box, Electric Reheat Coil, Control

   The local control system shall modulate the variable volume damper and reheat coil in sequence to achieve the desired space temperature setpoint (adj.). When the space temperature exceeds the cooling setpoint (adj.), the variable air volume (VAV) damper shall modulate open. As the temperature falls, VAV damper modulates to minimum position.

Minimum position shall be based on schedule on drawings. After damper reaches minimum position, the space temperature shall drift in a dead-band until reaching the heating control setpoint. As temperature continues to fall below setpoint, reheat coil shall modulate on. There are two modes of operation for setpoints, one for "occupied" and one for "unoccupied" mode.

3. Morning Warm-Up

Upon a command provided by the local control system the morning warm-up is enabled. When morning warm-up is enabled the VAV's respective controller shall position it damper to minimum position and reheat coil shall modulate until the space approaches its occupied setpoint at which time the boxes shall be put into occupied mode operation.

4. Occupied Mode

The system shall monitor the space temperature as sensed by its respective temperature sensor.

Upon a demand for cooling the VAV box shall increase the airflow to its maximum setting to maintain the space setpoint of 75 degrees F (adj.).

Upon a demand for heating the VAV box shall decrease the airflow to its minimum position and reheat coil shall modulate until the space approaches its temperature setpoint of 70 degrees F (adj.). If additional heat is required the setpoint shall be adjusted via the room temperature controller.

5. Unoccupied Mode

The VAV box damper shall remain in the closed position. On a further drop in space temperature the damper shall modulate to its minimum position to provide air to maintain a night setback temperature of 65 degrees F (adj.) in heating, 80 degrees F in cooling mode.

Coordinate with the owner which space sensors shall have the ability to override the system in the occupied mode for a period of 3 hours. This sensor shall have a tag above it, indicating the night setback zone sensor.

B. ALARMS

1. Fan Failure

If status of a fan, which has been called by the local control system to start, has not been verified as running within a period of 10 seconds (adj.), an alarm shall be sent to the operator's workstation. The fan shall be identified by its designation (AHU-#) or by a description of what it serves. (AHU-# supply fan) and shall be tagged as a "FAN FAILURE".

2. Exhaust Air Fan Failure

If status of a fan, which has been called by the local control systems to start, has not been identified as running within a period of 10 seconds (adj.), an alarm shall be sent to the

operator's workstation. The fan shall be identified by its designation (EF-#) or by a description of what it serves and shall be tagged as an "EXHAUST FAN FAILURE".

3. Filter Maintenance

A differential pressure switch with sensors on upstream and downstream side of filter shall signal the local control system when the differential pressure is equal to or greater than the setpoint (adj.). The local controller shall initiate an alarm signal at the operator's workstation indicating a clogged filter and requirement for maintenance.

4. Discharge air temperature

If the unit discharge air temperature is greater than 15 degrees F (adj) from setpoint the local controller shall initiate an alarm signal at the operator's workstation.

5. Smoke Detector Alarm

If the smoke detector in the supply air duct has been activated, a signal, via hard wire interlock, shall shut down the supply fan immediately and send a signal directly to the fire alarm control panel, by others. The building fire alarm panel shall send a direct digital signal to the local controller and an alarm shall be sent to the operator's workstation. It shall be tagged as "BUILDING FIRE ALARM".

6. High Space Temperature Alarm

If the space temperature is offset by more than 5 degrees F (adj.) above setpoint for a period of 5 minutes (adj.) an alarm shall be sent to the operator's workstation. The unit shall be identified by its room location (Room #) and shall be tagged as a "SPACE TEMPERATURE HIGH LIMIT ALARM".

7. Low Space Temperature Alarm

If the space temperature is less than 5 degrees F (adj.) below setpoint for a period of 5 minutes (adj.) an alarm shall be sent to the operator's workstation. The unit shall be identified by its room location (Room #) and shall be tagged as a "SPACE TEMPERATURE LOW LIMIT ALARM".

8. Condensate Pan Level Alarm

A conductivity probe assembly shall be provided in the air handling unit condensate pan to detect the level of condensate in the coil drain pan. In the event that the level of the condensate rises above the probe's detection mechanism The BMS shall initiate an alarm signal at the operator's workstation.

1.5 TERMINAL UNIT CONTROL SEQUENCES

A. Exhaust fans (EF):

1. Exhaust Fan (General, Toilet Rooms): The exhaust fan shall be controlled via a local controller). During the occupied mode, the exhaust fans shall be started and shall run continuously. Any associated dampers shall be open. If status of the fan, which has been

started by the DDC System, has not been verified as running within a period of 10 seconds, an alarm shall be sent to the operator's workstation.

PRODUCTS (Not Applicable)

PART 2 - EXECUTION (Not Applicable)

END OF SECTION 230993

SECTION 232923 - VARIABLE-FREQUENCY MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes separately enclosed, preassembled, combination VFCs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. CE: Conformite Europeene (European Compliance).

C. CPT: Control power transformer.

D. EMI: Electromagnetic interference.

E. LED: Light-emitting diode.

F. NC: Normally closed.

G. NO: Normally open.

H. OCPD: Overcurrent protective device.

I. PID: Control action, proportional plus integral plus derivative.

J. RFI: Radio-frequency interference.

K. VFC: Variable-frequency motor controller.

1.4 ACTION SUBMITTALS

A. Product Data: For each type and rating of VFC indicated.

1. Include dimensions and finishes for VFCs.
2. Include rated capacities, wiring diagrams, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings: For each VFC indicated.

1. Include mounting and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Required working clearances and required area above and around VFCs.
2. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements.
3. Show support locations, type of support, and weight on each support.
4. Indicate field measurements.

B. Qualification Data: For testing agency.

C. Product Certificates: For each VFC from manufacturer.

D. Harmonic Analysis Report: Provide Project-specific calculations and manufacturer's statement of compliance with IEEE 519.

E. Source quality-control reports.

F. Field quality-control reports.

G. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

a. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings.
b. Manufacturer's written instructions for setting field-adjustable overload relays.
c. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
d. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

e. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
f. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

1.9 DELIVERY, STORAGE, AND HANDLING

A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.

1.10 WARRANTY

A. Special Warranty: Manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: An 18-month warranty shall be provided on materials and workmanship from the date of shipment.

PART 2 - PRODUCTS

2.1 SUMMARY

A. This section provides specification requirements for solid-state, pulse-width modulated (PWM) Adjustable Frequency Drives, herein referred to as AC Drives, for use with NEMA® design NEMA B AC motors, or standard IEC motors.

B. The AC Drive supplier shall furnish, field test, adjust and certify all installed AC Drives for satisfactory operation.

C. Any exceptions/deviations to this specification shall be indicated in writing and submitted no less than one week prior to bid date.

2.2 REFERENCES

A. ANSI®/NFPA® 70 - National Electrical Code® (NEC®).

B. UL 508 - UL Standard for Safety Industrial Control Equipment.

C. UL 508C - UL Standard for Safety Power Conversion Equipment.

D. NEMA ICS7 : Industrial Control and Systems Variable Speed Drives.

E. CSA C22.2 No. 14-M91 : Industrial Control Equipment

F. IEC 1800 : Adjustable speed Electrical power drive systems

G. SEMI-F47: Voltage Ride Thru

2.3 GENERAL DESCRIPTION

A. The AC Drive shall convert the input AC mains power to an adjustable frequency and voltage

B. The input power section shall utilize a full wave bridge design incorporating diode rectifiers. The diode rectifiers shall convert fixed voltage and frequency, AC line power to fixed DC voltage.

C. The output power section shall change fixed DC voltage to adjustable frequency AC voltage.

D. The adjustable frequency drive package shall include input EMI/RFI filtering.

E. The AC drive shall have a user interface (keypad) that presents information in plain English / Spanish / French text. The user interface shall include a Local / Remote button to switch between control at the terminal strip and the user interface (keypad). This button shall also switch between network control and the user interface (keypad). The keypad shall have Run and Stop keys and a manual speed potentiometer function.

2.4 MANUFACTURERS

A. Manufacturers: Subject to compliance with the requirements, provide products by one of the following:

1. Schneider Electric USA, Inc Square D. (Basis of Design)
2. ABB
3. Eaton Electrical Inc: Cutler Hammer business unit

2.5 ENCLOSURES

A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1.
2. Outdoor Locations: Type 3R.
3. Other Wet or Damp Indoor Locations: Type 4.
4. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

2.6 CONSTRUCTION

A. The AC Drive power converter shall be UL Plenum rated.

1. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."

B. All heat sink fans shall be accessible from the front and shall not require the removal of the AC drive power converter for fan replacement.

C. All heat sink fans shall be cycled on only when required to cool the drive to maximize the life of the fan

D. When a Type 12 conduit entrance kit is required. The kit shall attach and be ground to the bottom of the AC drive and provide conduit landing for incoming line power cables, motor lead cable, control wiring, and network cabling.

2.7 APPLICATION DATA

A. The AC Drive shall be sized to operate a variable torque load.

B. The speed range shall be from a minimum speed of 1.0 Hz to a maximum speed of 72 Hz.

2.8 ENVIRONMENTAL RATINGS

A. The AC Drive shall meet IEC 60664-1 Annex A and NEMA ICS 1, UL, and CSA standards.

B. The AC Drive shall be designed to operate in an ambient temperature from -10 to 50 ˚C (14 to 122 ˚F).

C. AC Drives in Type 12 enclosures shall be designed to operate in an ambient temperature from -10 to 40 ˚C (14 to 104 ˚F).

D. Provide internal heaters as required to provide operation down to 0 degrees F.

E. The storage temperature range shall be -25 to 65 ˚C (-13 to 149 ˚F).

F. The maximum relative humidity shall be 95%, non-condensing.

G. The AC Drive shall be rated to operate at altitudes less than or equal to 3300 ft (1000 m).

H. For altitudes above 3300 ft (1000 m), the AC Drive should be de-rated per drive specifications.

I. The AC Drive shall meet the IEC 60721-3-3-3M3 operational vibration specification.

2.9 RATINGS

A. The AC Drive shall be designed to operate at the input line voltage indicated on the equipment schedule.

B. The AC Drive shall operate from an input frequency range of 60 Hz (±) 5%.

C. The displacement power factor shall not be less than .98 lagging under any speed or load condition.

D. The efficiency of the AC Drive at 100% speed and load shall not be less than 97%.

E. The variable torque rated AC Drive over current capacity shall be not less than 110% for 1 minute.

F. The output carrier frequency shall be randomly modulated about the selected frequency. The output carrier frequency of the AC Drive shall be selectable from 1 to 16 kHz, 12kHz nominal rating for 1-60 hp @ 200/240 V, 1-100 hp @ 380/480 V. Selectable: 2.5 to 8 kHz, 2.5kHz nominal rating for 75-125 hp @ 200/240 V, 125-900 hp @ 380/480 V.

2.10 PROTECTION

A. Upon power-up, the AC Drive shall automatically test for valid operation of memory, loss of analog reference input, loss of communication, DC-to-DC power supply, control power and pre-charge circuit.

B. The AC drive shall be rated for UL minimum short circuit currents per given horsepower rating.

C. The AC Drive shall be protected against short circuits, between output phases and to ground.

D. The AC Drive shall have under-voltage power-loss ride through performance per the SEMI F-47 voltage ride through standard and certified by a third party.

E. The AC drive shall have a programmable ride-through function, which will allow the logic to maintain control for a minimum of one-second (60 cycles) without faulting.

F. An auto restart function will provide selectable time for restart attempts after the fault has disappeared and other operating conditions permit the restart. The restart shall be performed by a series of automatic attempts separated by increasingly longer periods of time. This period of time shall be selectable.

G. Upon loss of the analog process follower reference signal, the AC Drive shall be programmable to display a fault.

H. The AC Drive shall have a solid-state UL 508C listed overload protective device and meet IEC 60947.

I. The output frequency shall be software enabled to fold back when the motor is overloaded.

J. There shall be three skip frequency ranges that can be programmed to a bandwidth of ± 2.5 Hz.

2.11 ADJUSTMENTS & CONFIGURATIONS

A. The AC Drive shall be capable of storing the configuration in the keypad.

B. The acceleration and deceleration ramp times shall be adjustable from 0.05 to 999.9 seconds.

C. The memory shall retain and record run status and fault type of the past eight faults.

D. The software shall have an energy economy function that, when selected, will reduce the voltage to the motor when selected for variable torque loads. A constant volts/Hz ratio will be maintained during acceleration. The output voltage will then automatically adjust to meet the torque requirement of the load. Selectable volts/Hz ratio patterns does not meet specification, the function must be automatically optimized.

E. The AC Drive shall have macro configurations for HVAC and pump applications, PID regulator set-up and network set-up.

2.12 KEYPAD DISPLAY INTERFACE

A. A keypad display interface shall offer the modification of AC Drive adjustments through a touch keypad. All electrical values, configuration parameters, I/O assignments, application and activity function access, faults, local control, and adjustment storage, and diagnostics shall be accessible.

B. The AC Drive model number, torque type, software revision number, horsepower, output current, motor frequency and motor voltage shall be listed on the drive identification portion of the LCD display.

C. The keypad display shall have password protection that allows the keypad to be locked out from unauthorized personnel.

D. The keypad shall be capable of displaying I/O assignment and status.

2.13 CONTROL CONNECTIONS

A. The control power for the digital inputs and outputs shall be 24Vdc.

B. The internal power supply shall incorporate automatic current fold-back that protects the internal power supply if incorrectly connected or shorted. The transistor logic outputs will be current limited and will not be damaged if shorted.

C. Removable terminal strips shall be used on all logic and analog signal connections in the power converter.

D. Two voltage-free relay output contacts will be provided. One of the contacts will indicate AC Drive fault status. The other contact shall indicate a drive run status. These relays shall be configurable for other status indicators.

E. The AC drive shall have a power removal logic input. The drive shall not allow the motor to operate until this input is closed. If this input is opened while the connected motor is running, the AC drive shall stop applying power to the motor. This power removal function shall be certified by an independent agency.

F. The control section of AC drive shall be supplied separately if necessary with 24V DC, to keep the network communication always available even if the power supply is OFF.

G. The drive shall include a damper solenoid end switch. Switch closure to be made prior to fan being energized.

H. Provide with preset speed input to accommodate high speed operation from auxiliary 24 V signal

2.14 dSERIAL COMMUNICATION

A. The AC Drive shall have an integrated RJ45 port, selectable for Modbus or CanOpen.

B. The AC drive shall have the capability for internal mounted communication card. The following protocols shall be the minimum available :

Industrial Installations	HVAC building Installations
- Ethernet TCP/IP - Modbus Plus - FIPIO - Profibus DP - Device Net - InterBus-S	-Lonworks -BACnet

2.15 HARMONIC MITIGATION

A. Each drive shall include a combination of integrated filters and DC link reactors to provide effective harmonic mitigation equivalent to 3% impedance without requiring additional panel space.

PART 3 - EXECUTION

3.1 INSPECTION

A. Verify that the location is ready to receive work and the dimensions are as indicated.

3.2 PROTECTION

A. Before and during the installation, the AC Drive equipment shall be protected from water and site contaminants.

3.3 INSTALLATION

A. Wall-Mounting Controllers: Install with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor, unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems."

B. Roof-Mounting Controllers: Install VFC on roofs with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished roof surface unless otherwise indicated, and by bolting units to curbs or mounting on freestanding, lightweight, structural-steel channels bolted to curbs. Seal roof penetrations after raceways are installed.

1. Curbs and roof penetrations are specified in Section 077200 "Roof Accessories."
2. Structural-steel channels are specified in Section 260529 "Hangers and Supports for Electrical Systems."

C. Comply with NECA 1.

D. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the VFD installation manual.

E. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 wiring requirements based on the VFD input current. Caution: VFDs supplied without internal reactors have substantially higher input current ratings, which may require larger input power wiring and branch circuit protection. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

F. Installation shall be in compliance with manufacturer's instructions, drawings and recommendations.

G. The AC Drive supplier shall provide a representative to inspect the contractor's installation, test and start-up the AC Drive(s) furnished under this specification.

3.4 DOCUMENTATION

A. The AC Drive supplier shall supply a comprehensive bound instruction and installation manual that includes wiring diagrams, layout diagrams, and outline dimensions. This manual must be insertion in a shop manual supplied by the installing contract.

3.5 SYSTEM DESCRIPTION

A. General Requirements for VFCs:

1. VFCs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.

B. VFC Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

C. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

D. Output Rating: Three phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range] [66 Hz, with torque constant as speed changes; maximum voltage equals input voltage.

E. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

1. Signal: Electrical.

F. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to 999.9 seconds.

4. Deceleration: 0.1 to 999.9 seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.

G. Self-Protection and Reliability Features:

1. Surge Suppression: Factory installed as an integral part of the VFC, complying with UL 1449 SPD, Type 1 or Type 2.
2. Surge Suppression: Field-mounted surge suppressors complying with Section 264313 "Surge Protection for Low-Voltage Electrical Power Circuits," UL 1449 SPD, Type 2.
3. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
4. Under- and overvoltage trips.
5. Inverter overcurrent trips.
6. VFC and Motor-Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor-overload alarm and trip; settings selectable via the keypad.
7. Critical frequency rejection, with three selectable, adjustable deadbands.
8. Instantaneous line-to-line and line-to-ground overcurrent trips.
9. Loss-of-phase protection.
10. Reverse-phase protection.
11. Short-circuit protection.
12. Motor-overtemperature fault.

H. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

I. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

J. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

K. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

L. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

3.6 CONTROLS AND INDICATION

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.

4. Line fault.
5. Overcurrent.
6. External fault.

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

    a. Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.

C. Historical Logging Information and Displays:

1. Real-time clock with current time and date.
2. Running log of total power versus time.
3. Total run time.
4. Fault log, maintaining last four faults with time and date stamp for each.

D. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFC door and connected to display VFC parameters including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).

E. Control Signal Interfaces:

1. Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:

    a. 0- to 10-V dc.
    b. 4- to 20-mA dc.
    c. Potentiometer using up/down digital inputs.
    d. Fixed frequencies using digital inputs.

2. Output Signal Interface: A minimum of one programmable analog output signal(s) 4- to 20-mA dc, which can be configured for any of the following:

a. Output frequency (Hz).
b. Output current (load).
c. DC-link voltage (V dc).
d. Motor torque (percent).
e. Motor speed (rpm).
f. Set point frequency (Hz).

3. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

a. Motor running.
b. Set point speed reached.
c. Fault and warning indication (overtemperature or overcurrent).
d. PID high- or low-speed limits reached.

F. BAS Interface: Factory-installed hardware and software shall interface with BAS to monitor, control, display, and record data for use in processing reports. VFC settings shall be retained within VFC's nonvolatile memory.

1. Hardwired Points:

a. Monitoring: On-off status.
b. Control: On-off operation.

3.7 SOURCE QUALITY CONTROL

A. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.

1. Test each VFC while connected to a motor that is comparable to that for which the VFC is rated.
2. Verification of Performance: Rate VFCs according to operation of functions and features specified.

B. VFCs will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.8 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.

B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.

D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work

E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.9 CONTROL WIRING INSTALLATION

A. Install wiring between VFCs and remote devices and facility's central-control system. Comply with requirements in Section 260523 "Control-Voltage Electrical Power Cables."

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic-control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.
2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protectors.

3.10 IDENTIFICATION

A. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFC with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.11 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections with the assistance of a factory-authorized service representative.

D. Acceptance Testing Preparation:

1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

E. Tests and Inspections:

1. Inspect VFC, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Engineerbefore starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
8. Perform the following infrared (thermographic) scan tests and inspections, and prepare reports:

    a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.
    b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Substantial Completion.
    c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

F. VFCs will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.12 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

3.13 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed 8 times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify Engineer before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable pressure switches.

3.14 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.15 DEMONSTRATION

A. Train owner's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

END OF SECTION 262923

SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Single-wall round ducts and fittings.
3. Sheet metal materials.
4. Duct Liners.
5. Sealants and gaskets.
6. Hangers and supports.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" Volume Four and performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Structural Performance: Hangers and supports for ductwork shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.

2. Sealants and gaskets.

1.5 INFORMATIONAL SUBMITTALS

A. Shop Drawings:

1. Lined ductwork
2. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
3. Factory- and shop-fabricated ducts and fittings.
4. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
5. Ceiling devices and associated airflow rates.
6. Elevation of top of ducts.
7. Dimensions of main duct runs from building grid lines.
8. Fittings.
9. Reinforcement and spacing.
10. Seam and joint construction.
11. Penetrations through fire-rated and other partitions.
12. Equipment installation based on equipment being used on Project.
13. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
14. Hangers and supports, including methods for duct and building attachment and vibration isolation.
15. Sheet metal thicknesses

B. Coordination Drawings: Plans and other details, drawn to scale, on which components are shown and coordinated with each other, using input from installers of the items involved. Refer to Specification Section 230010 General Mechanical Requirements for further information

C. Welding certificates.

D. Field quality-control reports

1.6 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" volume four based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 SINGLE-WALL ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Lindab Inc.
    b. McGill AirFlow LLC.
    c. SEMCO Incorporated.
    d. Sheet Metal Connectors, Inc.
    e. Spiral Manufacturing Co., Inc.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams,"

for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

D. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

E. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.4 DUCT LINER

A. Flexible Elastomeric Noise Reducing Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Armacell LLC, Coilflex.
b. Aeroflex USA Inc
c. Rubatex International, LLC

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

3. Minimum thermal conductivity: .25 BTU-in/h-ft^2-F
4. Rated for 180 degree F max and -297 degree F min
5. Noncorrosive
6. Antimicrobial
7. Sound transmission rating: 25
8. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

    a. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm.
7. **Adhere to duct with adhesive and secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally**.
8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

    a. Fan discharges.
    b. Intervals of lined duct preceding unlined duct.
    c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

2.5 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: 3 inches.
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
10. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers.

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.6 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

E. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

A. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. All ductwork: Seal class A

3.4 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.

4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Test the following systems:

    a. Ducts with a Pressure Class Higher Than 2-Inch wg: Test representative duct sections no less than 25 percent of total installed duct area for each designated pressure class.

3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
4. Test for leaks before applying external insulation.

5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
6. Give fourteen days' advance notice for testing.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

    a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.8 DUCT CLEANING

A. Clean new and existing duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.

5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.9 START UP

A. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC."

3.10 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

B. Supply, Return, Exhaust, and Outside Air:

a. Pressure Class: Positive 3-inch wg Negative 2- inch wg
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 24.
d. SMACNA Leakage Class for Round: 24

2. Ducts within wet environments:

a. Type 316, stainless-steel sheet.

1) Exposed to View: No. 3 finish.
2) Concealed: No. 2B finish.

b. Pressure Class: Positive or negative 3-inch wg.

c. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
d. SMACNA Leakage Class: 3.

C. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel or carbon steel coated with zinc-chromate primer.
2. Stainless-Steel Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Galvanized.

D. Liner:

1. Air Ducts specifically identified with an “L” after the duct size on drawings:

a. Flexible elastomeric noise reducing duct liner: 1 inches thick

E. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

1) Velocity up to 1500 fpm: 1.5 radius-to-diameter ratio and four segments for 90-degree elbow.

b. Round Elbows, 8 Inches and Smaller in Diameter: Stamped.
c. Round Elbows, 10 Inches and Larger in Diameter: 5 Gore, Welded.

A. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

a. Rectangular Main to Rectangular Branch: 45-degree lateral or 90-degree with 45-degree entry.

2. Rectangular Main to Round Tap: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

    a. Velocity 1000 fpm or Lower: 90-degree tap.
    b. Velocity 1000 to 1500 fpm: Conical tap.
    c. Velocity 2000 fpm or Less: 45-degree lateral or 90-degree with 45-degree entry.

END OF SECTION 233113

SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Manual volume dampers.
3. Control dampers.
4. Fire dampers.
5. Smoke dampers.
6. Combination Fire/Smoke dampers.
7. Flange connectors.
8. Turning vanes.
9. Duct-mounted access doors.
10. Flexible connectors.
11. Duct accessory hardware
12. Flexible ducts.

1.3 ACTION SUBMITTALS

A. Product data

B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

a. Special fittings.
b. Manual volume damper installations.
c. Control-damper installations.
d. Fire-damper damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
e. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fusible Links: Furnish 1 for each damper requiring fusible links installed

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections

2.2 MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Exposed-Surface Finish: Mill phosphatized.

B. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2 finish for concealed ducts and a No.3 finish for exposed ducts

C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches

2.3 BACKDRAFT AND PRESSURE RELIEF DAMPERS

A. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:

1. Description: Gravity balanced.
2. Maximum Air Velocity: 2500 fpm.
3. Maximum System Pressure: 2-inch wg.
4. Temperature: 180 degrees F
5. Frame: 18 gauge galvanized sheet steel, 3.5 in wide with welded corners and mounting flange.
6. Blades: .025 in thick roll-formed aluminum, center-pivoted, with sealed edges.
7. Blade Action: Parallel.
8. Blade Seals: extruded vinyl
9. Blade Axles:

    a. Material: Plated steel.
    b. Diameter: .1875 in

10. Tie Bars and Brackets: 20 gauge galvanized steel (on-blade)
11. Return Spring: Adjustable tension.
12. Bearings: Acetal.
13. Accessories:

    a. Adjustment device to permit setting for varying differential static pressure

2.4 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Manufacturers: provide products by one of the following:

    a. Greenheck Fan Corporation
    b. Nailor Industries Inc.
    c. Ruskin Company.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:

    a. Frame: Hat-shaped, 16 gauge, 5 inch deep, galvanized sheet steel.
    b. Mitered and welded corners.
    c. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

    a. Single blade up to 12” high, multi blade over 12” high
    b. Parallel- or opposed-blade design.
    c. Stiffen damper blades for stability.

d. Galvanized, V-blade, 16 gauge but not less than two gauges more than the duct gauge

6. Blade Axles: Galvanized steel, ½ inch diameter.
7. Bearings:

a. Stainless-steel sleeve.
b. Dampers in ducts with pressure classes of 2-inch wg or more and on all dampers over 12 inch diameter shall have continuous rod axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.
9. Include elevated platform for insulated duct mounting.
10. Damper handles:

a. Cast alloy body and core
b. Heavy stamped handle
c. Locking
d. Hex locking nut and acorn nut
e. Basis of design: Duro Dyne, Specline or approved equal

B. Cable Operated Manual Volume Damper Operator:

1. Manufacturer:

a. Bowden Cable Control System
b. As approved by the Engineer

2. Damper equal in construction to part A above:

3. Operator:

a. Rack and Pinion controller shall be minimum 14 gauge galvanized steel. Shall deliver minimum 35 inch-pounds of push-pull torque.
b. Outer casing shall be minimum 3/16” galvanized steel
c. Inner wire shall be type 302 stainless steel. Shall have a minimum tensile strength of 265,000 pounds
d. Mounting bracket shall be minimum 18 gauge galvanized steel with heat treated carbon steel self-clinching fastener.
e. Threaded screw cap sall be zinc plated steel 1” flathead, ready for prime and paint.

4. Remote Control, Blade Type, Damper Operator:

a. Manufacturers:

1) United Enertech Power Balance
2) As approved by the Engineer

b. Warranty: Dampers shall be warranted against manufacturing defects for a period of one year.

c. Damper Ratings:

1) Temperature Rating: 35 -120 deg F.
2) Maximum Velocity: 2600 FPM
3) Maximum Differential Pressure Rating: 3” w.g.

d. Construction:

1) Frame: 24 gauge galvanized steel minimum with milled finish
2) Blade: 24 gauge galvanized steel, mechanically fastened to axel with milled finish.
3) Axel(s): Zinc plated steel steel pins.
4) Bearings: Nylon 6/6 molded synthetic.
5) Mounting: Vertical or Horizontal.
6) Actuator: DC Voltage, direct drive, electronic pulse.
7) Remote: Portable hand held power pack with RJ-11 cable.

e. Accessories:

1) RJ-11 cable per damper, length as needed.
2) RJ-11 cable termination point, termination quantities as needed. Terminations shall be labeled to corresponding damper.

2.5 FIRE AND SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance; a division of MESTEK
2. Greenheck Fan Corporation.
3. Ruskin Company.

B. Fire Dampers (Curtain Style):

1. Type: Static [Dynamic]; rated and labeled according to UL 555 by an NRTL.
2. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
3. Fire Rating: 1-1/2 [3] hours.
4. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.
5. Mounting Sleeve: Factory installed galvanized sheet steel. Provide with breakaway duct connections.

a. Minimum Thickness: 0.05 thick, as indicated, and of length to suit application.
b. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

6. Mounting Orientation: Vertical or horizontal as indicated.
7. Blades: Galvanized curtain style

8. Heat-Responsive Device: Replaceable, 165 [212] deg F rated, fusible links.

C. Fire Dampers (Airfoil Style):

1. Type: Static [Dynamic]; rated and labeled according to UL 555 by an NRTL.
2. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
3. Fire Rating: 1-1/2 [3] hours.
4. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.
5. Mounting Sleeve: Factory installed, galvanized sheet steel. Provide with breakaway duct connections.

    a. Minimum Thickness: 0.05 thick, as indicated, and of length to suit application.
    b. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

6. Mounting Orientation: Vertical or horizontal as indicated.
7. Blades: Roll-formed, interlocking 0.024 inch thick galvanized sheet steel.
8. Heat-Responsive Device: Replaceable, 165 [212] deg F rated, fusible links.

D. Smoke Dampers:

1. General Requirements: Label according to UL 555S by an NRTL.
2. Frame: Hat-shaped, 0.094-inch thick, galvanized sheet steel, with welded, interlocking, gusseted, or mechanically attached corners and mounting flange.
3. Blades: Roll-formed, interlocking 0.024 inch thick galvanized sheet steel.
4. Leakage: Class I; 4.0 cfm/ft^2 at 1” w.g.
5. Rated pressure and velocity to exceed design airflow conditions.
6. Mounting Sleeve: Factory-installed 0.039 inch thick galvanized sheet steel; length to suit wall or floor application.
7. Mounting Orientation: Vertical or horizontal as indicated.
8. Damper motor: Two-position action.
9. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors.
10. Electrical connection: 115/1/60 [24 volt].

E. Combination Fire/Smoke Dampers:

1. Type: Static [Dynamic]; rated and labeled according to UL 555 and UL 555S by an NRTL.
2. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
3. Fire Rating: 1-1/2 [3] hours.
4. Frame: Hat-shaped, 0.094-inch thick, galvanized sheet steel, with welded, interlocking, gusseted, or mechanically attached corners and mounting flange.
5. Heat-Responsive Device: Replaceable, 165 [212] deg F rated, fusible links.
6. Blades: Roll-formed, interlocking 0.024 inch thick galvanized sheet steel.
7. Leakage: Class I; 4.0 cfm/ft^2 at 1” w.g.
8. Rated pressure and velocity to exceed design airflow conditions.

9. Mounting Sleeve: Factory-installed 0.039 inch thick galvanized sheet steel; length to suit wall or floor application. Provide with breakaway duct connections
10. Mounting Orientation: Vertical or horizontal as indicated.
11. Damper motor: Two-position action.
12. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors.
13. Electrical connection: 115/1/60 [24 volt].

2.6 FLANGE CONNECTORS

A. Interior

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Ductmate Industries, Inc.
    b. Nexus PDQ; Division of Shilco Holdings Inc.
    c. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

2. Description: roll-formed, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.
3. Material: Galvanized steel.
4. Gage and Shape: Match connecting ductwork.

2.7 TURNING VANES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. Elgen Manufacturing.
4. METALAIRE, Inc.
5. SEMCO Incorporated.
6. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

C. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."

D. Vane Construction: Single Wall for ducts up to 36 inches wide and double wall for larger dimensions.

E. Vane Spacing: 1.5 inches.

F. Vane Radius: 2 inches.

2.8 DUCT-MOUNTED ACCESS DOORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Greenheck Fan Corporation.
3. Nailor Industries Inc

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2, "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."

1. Door:

   a. Double wall, rectangular.
   b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
   c. Vision panel.
   d. Hinges and Latches: 1-by-1-inch piano hinge and cam latches.
   e. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

   a. Access Doors up to 18 Inches Square: Two hinges and two sash locks.
   b. Access Doors up to 24 by 48 Inches: Three hinges and two compression latches with outside and inside handles.
   c. Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

C. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: Double wall with insulation fill with metal thickness applicable for duct pressure class.
3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
4. Factory set at 10-inch wg.
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.
7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
9. Insulation Fill: 1-inch thick, fibrous-glass or polystyrene-foam board

2.9 FLEXIBLE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. Elgen Manufacturing.
4. Ventfabrics, Inc.
5. Ward Industries, Inc.; a division of Hart & Cooley, Inc

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 5-3/4 inches wide attached to 2 strips of 2-3/4-inch wide, 0.028-inch thick, galvanized sheet steel or 0.032-inch thick aluminum sheets. Provide metal compatible with connected ducts.

E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd..
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.

2.10 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

2.11 FLEXIBLE DUCTS

A. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:

B. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film.

1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 175 deg F.
4. Insulation R-Value: Comply with ASHRAE/IESNA 90.1.

C. Flexible ducts to be provided for supply air ductwork only or as otherwise shown on drawings.

D. Flexible Duct Connectors:

1. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action in sizes 3 through 18 inches, to suit duct size.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install control dampers at outlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Provide volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Dampers shall be provided as necessary to achieve a NEBB certified air balance.

1. Install steel volume dampers in steel ducts.
2. Install stainless steel volume dampers in stainless steel ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Remote volume damper operator: Install where volume dampers are shown on contract documents above inaccessible ceiling. Operator shall be adjustable by removing 1” screw cap. Rack and pinion controller mounted to “C” bracket. Bracket shall fasten to a ceiling support stud above the ceiling. Airflow adjustment tool shall be provided, one tool per 10 operators.

G. Remote control damper operator: Install where volume damper as shown on contract documents above inaccessible ceiling. Install terminal wall point and connect RJ-11 cable between damper and terminal point. Support wire per division 26 ‘Wiring’ sections. Group terminal points at single location as practical, review terminal point location(s) with Engineer or Owner’s Representative.

H. Install test holes at fan inlets and outlets and elsewhere as indicated.

I. Install fire dampers according to UL listing.

J. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. At outdoor-air intakes and mixed-air plenums.
3. At drain pans and seals.
4. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
5. Adjacent to and close enough to fire dampers, to reset or reinstall fusible links. Access doors for access to fire dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.

6. Upstream and downstream from turning vanes.
7. Upstream or downstream from duct silencers.
8. Control devices requiring inspection.
9. Elsewhere as indicated.

K. Install access doors with swing against duct static pressure.

L. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
3. Head and Hand Access: 18 by 10 inches.
4. Head and Shoulders Access: 21 by 14 inches.
5. Body Access: 25 by 14 inches.
6. Body plus Ladder Access: 25 by 17 inches.

M. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

N. Install flexible connectors to connect ducts to equipment.

O. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

P. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.

Q. Connect diffusers to ducts directly or with maximum 60-inch lengths of flexible duct clamped in place with stainless steel band clamps.

R. Connect flexible ducts to metal ducts with stainless steel band clamps, adhesive, and sheet metal screws.

S. Install duct test holes where required for testing and balancing purposes.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.
6. Verify all dampers are secured and handles can be correctly fastened to hold damper in place.

END OF SECTION 233300

SECTION 233600 - AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-duct air terminal units.
2. Casing Liner.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of air terminal unit.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for air terminal units.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings:

1. Include plans, elevations, sections, and mounting details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Hangers and supports, including methods for duct and building attachment and vibration isolation.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Refer to specification section 230010 “General Mechanical Requirements” for further information on coordination drawings.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. O&M information shall include the following:

1. Instructions for resetting minimum and maximum air volumes.
2. Instructions for adjusting software set points

1.6 QUALITY ASSURANCE

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Insulation shall meet NFPA 90A requirements for flame spread and smoke generation and UL 181 requirements for anti-erosion, corrosion and fungus properties. Any sealant used shall also conform to NFPA 90A and be approved for duct use.

D. ASHRAE Compliance: Applicable requirements in ASHRAE/IES 90.1, "Section 6 - Heating, Ventilating, and Air Conditioning."

E. Sound power levels shall be AHRI certified in accordance with the requirements of AHRI 880.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Unless otherwise indicated within the specification, and subject to compliance with requirements, provide products by one of the following:

1. Trane (Basis of Design)
2. Price Industries.
3. Titus.

2.2 PERFORMANCE REQUIREMENTS

A. Structural Performance: Hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"

2.3 SINGLE-DUCT AIR TERMINAL UNITS

A. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

B. Casing: 20 gauge galvanized steel, single wall.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for duct liner.
2. Air Inlet: Product and material, appropriate for the metal gauges being joined, the maximum pressure, and SMACNA recommendations, to result in a rigid, leak-free duct connection. All connections shall be sealed using an appropriate duct sealant method unless a slide-on transverse duct connector sold with a guaranteed leak-free sealing feature is used.
3. Air Outlet: Product and material, appropriate for the metal gauges being joined, the maximum pressure, and SMACNA recommendations, to result in a rigid, leak-free duct connection. All connections shall be sealed using an appropriate duct sealant method unless a slide-on transverse duct connector sold with a guaranteed leak-free sealing feature is used.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket. Access door located on the bottom of the terminal.
5. Leakage through the casing shall be less than 1% of the maximum rated air flow at 3" w.c. static pressure.

C. Casing Liner: 1-inch thick (min. R-4.2) rigid duct board insulation with nylon reinforced foil material covering the insulation fibers. Insulation shall meet UL 181 and NFPA 90A. The lining shall be attached to the terminal unit casing by insulation adhesive and full seam length steel Z-strips which enclose and seal the insulation cut edges. Taped edges shall not be accepted.

D. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from 0 - 140ºF, shall be impervious to moisture and fungus, shall be suitable for 10-inch wg static pressure, and shall be factory tested for leaks.

E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: AHRI 880 rated, less than 2% of nominal airflow at 3-inch wg inlet static pressure.
2. Damper Position: Nominal 90-degree, free rotation from fully opened to fully closed positions when mechanical stops are. The damper blade shall be mechanically attached to the die-cast metal damper shaft with through the shaft machine-applied rivets. The low leakage damper shall be constructed of a gasket material sandwiched between two 22-gauge zinc coated steel plates. The damper gasket material shall be securely fastened between the two damper plates using machine applied rivets. The damper assembly shall rotate freely in self-lubricating bearings. Damper position shall be indicated on the end of the shaft on the outside of the casing. Free rotation until factory-installed stops reached.

F. Attenuator Section: 20 gauge steel sheet.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for duct liner.

G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and

secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

1. SCR controlled.
2. Access door interlocked with disconnect switch.
3. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).
4. Nickel chrome 80/20 heating elements.
5. Airflow switch for proof of airflow.
6. Fan interlock contacts.
7. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
8. Mercury contactors.
9. Magnetic contactor for each step of control (for three-phase coils).

H. Control devices shall be compatible with roof top unit integral factory control system.

1. Electronic Damper Actuator: 24 V, powered open, spring return.
2. Electronic Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
3. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
4. Terminal Unit Controller: Pressure-independent, variable-air-volume (VAV) controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

    a. Occupied and unoccupied operating mode.
    b. Remote reset of airflow or temperature set points.
    c. Adjusting and monitoring with portable terminal.
    d. Communication with temperature-control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

5. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.

I. Controls:

1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg inlet static pressure.

2.4 SOURCE QUALITY CONTROL

A. Factory Tests: Test assembled air terminal units according to ARI 880.

1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, coil type, and ARI certification seal.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install chemical-actuated concrete fasteners after concrete is placed and completely cured.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.2 TERMINAL UNIT INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal unit(s) level and plumb. Maintain ready accessibility for routine service and maintenance. Unit shall be accessible within the reach of an 8-foot step ladder. Access shall not be hindered by building components. No maintainable parts of the unit, reheat coil, or appurtenance shall be crossed by a wall.

C. Install wall-mounted temperature sensors.

3.3 CONNECTIONS

A. Install piping adjacent to air terminal unit to allow service and maintenance.

B. Connect ducts to air terminal units according to Section 233113 "Metal Ducts”.

3.4 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

3.5 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Air terminal unit will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.6 STARTUP SERVICE

A. Perform startup service:

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
3. Verify that controls and control enclosure are accessible.
4. Verify that control connections are complete.
5. Verify that nameplate and identification tag are visible.
6. Verify that the building management system display accurately reflects the as-built condition and that the building management system responds and causes the terminal unit to respond as specified.
7. Verify that the identified terminal unit serves the area specified on the final drawings.

3.7 DEMONSTRATION

A. Train owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 233600

SECTION 233713 - DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Ceiling diffusers.
2. Linear slot diffusers.
3. Fixed face registers and grilles.

B. Related Sections:

1. Division 23 Section "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers, registers, and grilles.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, include the following:

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

1.4 INFORMATION SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

PART 2 - PRODUCTS

2.1 CEILING DIFFUSERS

A. Square Ceiling Diffusers:

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Devices shall be specifically designed for variable-air-volume flows.
3. Construction: Precision formed back cone of one-piece seamless construction that incorporates a round Intel collar of sufficient length for connecting rigid or flexible duct.
4. An inner plaque assembly shall be incorporated and shall drop no more than a ¼ inch below the ceiling plane to assure proper air distribution performance.
5. The inner plaque assembly shall be completely removable from the diffuser face to allow for full access to any dampers or other ductwork components located near the diffuser neck.
6. Material: Refer to drawings.
7. Finish: powder coat, color selected by Architect.
8. Paint finish shall pass 500 hours of salt spray exposure with no measurable creep in accordance with ASTM D1654 and 1000 hours with no rusting or blistering per ASTM D610 and ASTM D714.
9. Air pattern: 360 degree radial horizontal.
10. Face Size: Indicated on drawing per location.
11. Face Style: Plaque.
12. Mounting: Coordinate with architectural ceiling types for each diffuser shown and provide mounting frame specific for each ceiling type.
13. Dampers: Radial opposed blade.
14. Accessories:

    a. Equalizing grid.

2.2 LINEAR SLOT DIFFUSERS

A. Linear Slot Diffuser:

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Devices shall be specifically designed for variable-air-volume flows.
3. Construction: The diffuser border shall be heavy extruded aluminum construction with extruded aluminum spacers and mitered end flanges, open ends, flush end caps or angle end caps.
4. Joiner strips shall be provided to align continuous slot assemblies.
5. Finish - Face and Shell: Powder coat, color selected by Architect.
6. Finish - Pattern Controller: Powder coat, black.
7. Finish - Tees: Powder coat, color selected by Architect.
8. Paint finish shall pass 500 hours of salt spray exposure with no measurable creep in accordance with ASTM D1654 and 1000 hours with no rusting or blistering per ASTM D610 and ASTM D714
9. Slot: ¾” wide with aerodynamically curved “ice tong” shaped pattern control.

10. Number of Slots: Indicated on drawings per location.
11. Length: Indicated on drawings per location.
12. Air pattern: 180 degree adjustable horizontal
13. Accessories:

    a. Factory fabricated and insulated plenum box sized for the length of the diffuser.

        1) Construction: zinc coated steel
        2) Plenum assemblies shall be of a side inlet configuration
        3) Plenum shall have sloped shoulders for enhanced spread characteristics.
        4) Provide curved factory built plenums to accommodate curved diffuser

14. Coordinate with architectural ceiling types for each linear slot outlet shown and provide mounting frame specific for each ceiling type.

2.3 FIXED FACE REGISTERS AND GRILLES

A. Fixed Face Supply Register

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Registers shall be double deflection type with two sets of fully adjustable deflection blades spaced ¾ inch on center. The front blades shall run parallel to the long dimension of the register.
3. Material: Refer to drawings.
4. Finish: Powder coated, color selected by Architect.
5. Paint finish shall pass 500 hours of salt spray exposure with no measurable creep in accordance with ASTM D1654 and 1000 hours with no rusting or blistering per ASTM D610 and ASTM D714
6. Frame: 1-1/4 inches wide.
7. Mounting Frame: Welded with precision mitered corners.
8. Mounting: Countersunk screw.
9. Damper Type: Adjustable opposed blade. Damper shall be operable from the register face. Damper material to match register material.

B. Fixed Face Return and transfer Register

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Registers shall be 45 degree deflection fixed louver type with blades spaced ½ inch on center. The front blades shall run parallel to the long dimension of the register.
3. Material: Refer to drawings.
4. Finish: Powder coated, color selected by Architect.
5. Paint finish shall pass 500 hours of salt spray exposure with no measurable creep in accordance with ASTM D1654 and 1000 hours with no rusting or blistering per ASTM D610 and ASTM D714
6. Frame: 1-1/4 inches wide.
7. Mounting Frame: Welded with precision mitered corners.
8. Mounting: Countersunk screw.

9. Damper Type: Adjustable opposed blade. Damper shall be operable from the register face. Damper material to match register material.

C. Fixed Face Exhaust Register

1. Performance: Subject to compliance with requirements and related documents, provide products meeting a minimum performance of the following:
2. Registers shall be 45 degree deflection fixed louver type with blades spaced ½ inch on center. The front blades shall run parallel to the long dimension of the register.
3. Material: Refer to drawings
4. Finish: Powder coated, color selected by Architect.
5. Paint finish shall pass 500 hours of salt spray exposure with no measurable creep in accordance with ASTM D1654 and 1000 hours with no rusting or blistering per ASTM D610 and ASTM D714
6. Frame: 1-1/4 inches wide.
7. Mounting Frame: Welded with precision mitered corners.
8. Mounting: Countersunk screw.
9. Damper Type: Adjustable opposed blade. Damper shall be operable from the register face. Damper material to match register material.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713

SECTION 237200 - ROOF ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Roof curbs.
2. Equipment supports.
3. Duct supports.

1.3 COORDINATION

A. Coordinate layout and installation of roof accessories with roofing membrane and base flashing and interfacing and adjoining construction to provide a leakproof, weathertight, secure, and noncorrosive installation.

B. Coordinate dimensions with rough-in information or Shop Drawings of equipment to be supported.

1.4 ACTION SUBMITTALS

A. Delegated Design: Design roof accessories and associated anchors including comprehensive engineering analysis signed and sealed by a qualified professional engineer, licensed in the project location state, responsible for their preparation. Wind pressures are to be determined by delegated design engineer based on site specific wind criteria indicated below. All building attachments to be coordinated with structural conditions.

1. Detail fabrication and assembly of rooftop unit and roof curb.
2. Wind Design Loads:

    a. Basic wind speed: 105 MPH
    b. Exposure Category: C

        1) Refer to structural drawing S001 for additional structural design data.

B. Product Data: For each type of roof accessory.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. General Performance: Roof accessories shall withstand exposure to weather and resist thermally induced movement without failure, rattling, leaking, or fastener disengagement due to defective manufacture, fabrication, installation, or other defects in construction.

B. Structural Performance: Equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

C. Detail mounting, securing, and flashing of roof curb to roof structure and unit to roof curb. Indicate coordinating requirements with roof membrane system

2.2 ROOF CURBS

A. Roof Curbs: Internally reinforced roof-curb units capable of supporting superimposed live and dead loads, including equipment loads and other construction indicated on Drawings, bearing continuously on roof structure, and capable of meeting performance requirements; with welded or mechanically fastened and sealed corner joints, straight sides and integrally formed deck-mounting flange at perimeter bottom.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Greenheck Fan Corporation.
    b. Pate Company.
    c. Thybar Corporation (Basis of Design).

B. Size: Coordinate dimensions with roughing-in information or Shop Drawings of equipment to be supported.

C. Supported Load Capacity: Coordinate load capacity with information on Shop Drawings of equipment to be supported.

D. Material: Zinc-coated (galvanized) steel sheet, 18-gauge thick.

E. Construction:

1. Curb Profile: compatible with roofing system.
2. On ribbed or fluted metal roofs, form deck-mounting flange at perimeter bottom to conform to roof profile.
3. Fabricate curbs to minimum height of 24 inches above roofing surface unless otherwise indicated.
4. Top Surface: Level top of curb, with roof slope accommodated by sloped deck-mounting flange.
5. Sloping Roofs: Where roof slope exceeds 1:48, fabricate curb with perimeter curb height tapered to accommodate roof slope so that top surface of perimeter curb is level. Equip unit with water diverter or cricket on side that obstructs water flow.

6. Insulation: Factory insulated with 1-1/2-inch-thick glass-fiber board insulation.
7. Liner: Same material as curb, of manufacturer's standard thickness and finish.
8. Nailer: Factory-installed wood nailer under top flange on side of curb, continuous around curb perimeter.
9. Wind Restraint Straps and Base Flange Attachment: Provide wind restraint straps, welded strap connectors, and base flange attachment to roof structure at perimeter of curb, of size and spacing required to meet wind uplift requirements.
10. Platform Cap: Where portion of roof curb is not covered by equipment, provide weathertight platform cap formed from 3/4-inch- thick plywood covered with metal sheet of same type, thickness, and finish as required for curb.
11. Metal Counterflashing: Manufacturer's standard, removable, fabricated of same metal and finish as curb.

2.3 EQUIPMENT SUPPORTS

A. Equipment Supports: Rail-type metal equipment supports capable of supporting superimposed live and dead loads between structural supports, including equipment loads and other construction indicated on Drawings, spanning between structural supports; capable of meeting performance requirements; with welded or mechanically fastened and sealed corner joints, integral metal cant**,** and integrally formed structure-mounting flange at bottom.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Pate Company. (Basis of Design).
    b. Thybar Corporation.
    c. Custom Solution Roof and Metal Products

B. Size: Coordinate dimensions with roughing-in information or Shop Drawings of equipment to be supported.

C. Supported Load Capacity: Coordinate load capacity with information on Shop Drawings of equipment to be supported.

D. Material: Zinc-coated (galvanized) steel sheet,14-gauge thick.

E. Construction:

1. Curb Profile: Profile as indicated on Drawings compatible with roofing system.
2. Insulation: Factory insulated with 1-1/2-inch-thick glass-fiber board insulation.
3. Liner: Same material as equipment support, of manufacturer's standard thickness and finish.
4. Nailer: Factory-installed continuous wood nailers 5-1/2 inches wide under top flange on side of curb, continuous around support perimeter.
5. Wind Restraint Straps and Base Flange Attachment: Provide wind restraint straps, welded strap connectors, and base flange attachment to roof structure at perimeter of curb of size and spacing required to meet wind uplift requirements.
6. Platform Cap: Where portion of equipment support is not covered by equipment, provide weathertight platform cap formed from 3/4-inch- thick plywood covered with metal sheet of same type, thickness, and finish as required for curb.

7. Metal Counterflashing: Manufacturer's standard, removable, fabricated of same metal and finish as equipment support.
8. On ribbed or fluted metal roofs, form deck-mounting flange at perimeter bottom to conform to roof profile.
9. Fabricate equipment supports to minimum height of 12 inches above roofing surface unless otherwise indicated.
10. Sloping Roofs: Where roof slope exceeds 1:48, fabricate each support with height to accommodate roof slope so that tops of supports are level with each other. Equip supports with water diverters or crickets on sides that obstruct water flow.

2.4 DUCT SUPPORTS

A. Fixed-Height Cradle-Type Pipe Supports: Polycarbonate pipe stand accommodating up to 1-1/2-inch- diameter pipe or conduit; with provision for pipe retainer and with manufacturer's support pad or deck plate as recommended for penetration-free installation over roof membrane type; as required for quantity of pipe runs and sizes.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, to verify actual locations, dimensions, and other conditions affecting performance of the Work.

B. Verify that substrate is sound, dry, smooth, clean, sloped for drainage, and securely anchored.

C. Verify dimensions of roof openings for roof accessories.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install roof accessories according to manufacturer's written instructions.

1. Install roof accessories level; plumb; true to line and elevation; and without warping, jogs in alignment, buckling, or tool marks.
2. Anchor roof accessories securely in place so they are capable of resisting indicated loads.
3. Use fasteners, separators, sealants, and other miscellaneous items as required to complete installation of roof accessories and fit them to substrates.
4. Install roof accessories to resist exposure to weather without failing, rattling, leaking, or loosening of fasteners and seals.

B. Metal Protection: Protect metals against galvanic action by separating dissimilar metals from contact with each other or with corrosive substrates by painting contact surfaces with bituminous coating or by other permanent separation as recommended by manufacturer.

1. Coat concealed side of uncoated aluminum roof accessories with bituminous coating where in contact with wood, ferrous metal, or cementitious construction.

2. Underlayment: Where installing roof accessories directly on cementitious or wood substrates, install a course of underlayment and cover with manufacturer's recommended slip sheet.
3. Bed flanges in thick coat of asphalt roofing cement where required by manufacturers of roof accessories for waterproof performance.

C. Roof Curb Installation: Install each roof curb so top surface is level.

D. Equipment Support Installation: Install equipment supports so top surfaces are level with each other.

E. Gravity Ventilator Installation: Verify that gravity ventilators operate properly and have unrestricted airflow. Clean, lubricate, and adjust operating mechanisms.

3.3 REPAIR AND CLEANING

A. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing according to ASTM A780/A780M.

B. Clean exposed surfaces according to manufacturer's written instructions.

C. Clean off excess sealants.

D. Replace roof accessories that have been damaged or that cannot be successfully repaired by finish touchup or similar minor repair procedures.

END OF SECTION 237200

SECTION 237414 – PACKAGED ROOFTOP UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. Division 23 Section 230010- “General Motor Requirements for HVAC Equipment”

C. Division 26 Section 262923- “Variable Frequency Drives”

1.2 SUMMARY

A. This Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components:

1. Air-source heat pump heating and cooling.
2. Economizer outdoor- and return-air damper section.
3. Power exhaust fan.
4. Air filtration.
5. Roof curbs.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design rooftop fans, roof curbs, and associated anchors including comprehensive engineering analysis signed and sealed by a qualified professional engineer, licensed in the project location state, responsible for their preparation. Design to include rooftop fan, roof curb, and all associated anchors and fastener performance requirements. Wind pressures are to be determined by delegated design engineer based on site specific wind criteria indicated below. All building attachments to be coordinated with existing structural conditions.

1. Detail fabrication and assembly of fan and roof curb.
2. Wind Design Loads:

B. Wind-Restraint Performance:

1. Ultimate Wind Speed: 105 mph.
2. Exposure Category: C.

C. Structural Performance: Equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

D. Detail mounting, securing, and flashing of roof curb to roof structure and unit to roof curb. Indicate coordinating requirements with roof membrane system

1.4 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:

    a. Certified fan-performance curves with system operating conditions indicated.
    b. Certified fan-sound power ratings.
    c. Fan construction and accessories.
    d. Motor ratings, electrical characteristics, and motor accessories.
    e. Wiring diagrams

4. Certified coil-performance ratings with system operating conditions indicated.
5. Dampers, including housings, linkages, and operators.
6. Filters with performance characteristics.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring

C. Delegated-Design Submittal: For unit supports indicated above

1.5 INFORMATIONAL SUBMITTALS

A. Certificates: For certification required in "Quality Assurance" Article.

B. Field quality-control reports.

C. StaMAUp service reports.

D. Warranty: Sample of special warranty

E. Coordination Drawings: Plans and other details, drawn to scale, on which components are shown and coordinated with each other, using input from installers of the items involved. Refer to Specification Section 2300100 General Mechanical Requirements for further information.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Filters: One set of start-up filters, one set of replacement filters, and 1 set of extra filters for each unit.
2. Gaskets: One set for each access door.
3. Fan Belts: One set(s) for each air-handling unit fan

1.8 QUALITY ASSURANCE

A. Manufacturer Qualifications: Company specializing in manufacturing the products specified in this section with minimum five (5) years documented experience.

B. The product shall be provided by a single manufacturer.

C. The manufacturer authorized representative shall be factory trained and certified personnel providing service, start up, and quality control field labor for the project from their local office.

D. All components shall be factory tested and documented to operate as a complete system.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

G. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.

H. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and StaMAUp."

I. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

J. Units shall be manufactured in an ISO 9001 certified facility.

K. Units shall be CSA certified to ANSI Z21.47 and UL 1995/CAN/CSA No. 236-M90 standards

L. Comply with NFPA 70.

1.9 COORDINATION

A. Coordinate sizes and locations of roof curbs with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.10 WARRANTY

1. Provide 1-year parts and labor warranty associated with all components of the air handling unit. Warranty period to begin at substantial completion.
2. Compressor- 5 years from substantial completion.
3. Heat Exchanger- 10 years from substantial completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Trane. (Basis of Design)
2. York.
3. Carrier.

2.2 GENERAL

A. Unit shall be fully assembled and tested by the manufacturer in the factory in accordance with the arrangement shown on the drawings. Fans shall be tested and rated in accordance with AMCA Standard 210 or performance and in accordance with ANSI standards of testing for sounds power levels.

B. The unit shall be assembled into the largest sections possible subject to shipping and rigging restrictions. The correct fit of all components and casing sections shall be verified in the factory for all units prior to shipment. All units shall be fully assembled, tested and then split to accommodate shipment and job site rigging. On units not shipped fully assembled, the manufacturer shall tag each section and include air flow direction to facilitate assembly at the job site. Lifting lugs or shipping skids shall be provided for each section to allow for field rigging and final placement of unit. Unit manufacturer shall furnish unit with sufficient gasket and bolts for reassembly in the field.

C. The unit manufacturer shall provide the necessary gasketing, caulking, and all screws, nuts, and bolts required for assembly. The manufacturer shall provide a local representative at the job site to supervise the assembly and to assure the units are assembled to meet manufacturer's recommendations and requirements noted on the drawings. Provide documentation that this representative has provided this service on similar jobs to the Architect. If a local representative cannot be provided, the manufacturer shall provide a factory representative.

2.3 PACKAGED ROOFTOP UNITS

A. GENERAL

1. Unit shall be factory assembled and tested including leak testing of the DX coils, pressure testing of the refrigeration circuit, and run testing of the completed unit. Run test report shall be supplied with the unit in the service compartment’s literature pocket.

2. Unit shall have decals and tags to indicate lifting and rigging, service areas and caution areas for safety and to assist service personnel.
3. Unit components shall be labeled, including refrigeration system components and electrical and controls components.
4. Estimated sound power levels (dB) shall be shown on the unit ratings sheet.
5. Laminated color-coded wiring diagram shall match factory installed wiring and shall be affixed to the interior of the control compartment's hinged access door.
6. Unit nameplate shall be provided in two locations on the unit, affixed to the exterior of the unit and affixed to the interior of the control compartment's hinged access door.
7. Cooling capacity ratings shall be based on ARI Standard 210. Units shall consist of insulated weather-tight casing with compressors, air-cooled condenser coil, condenser fans, evaporator coil, return-air filters, supply motors and unit controls and drives.
8. The units shall be factory wired, piped and charged with R-454B refrigerant and factory tested prior to shipment.
9. Units meet the seismic capacity requirements of the International Code Council Evaluation Service (ICC- ES) document AC156 (Acceptance Criteria for Seismic Qualification by Shake- Table Testing of Nonstructural Components and Systems), the International Building Code (IBC 2009), and the California Building Code (CBC 2010) with quality testing conducted in accordance with the standards of the American Society of Civil Engineers (ASCE 7-05).

    a. Units are certified with an SDS (g) value of 2.50 using seismic design parameters of z/h=1.0, Ip=1.5 and certified by independent structural engineers

B. UNIT CASINGS

1. Cabinet: Galvanized steel. Exterior surfaces shall be finished with a non-chalking, powder paint finish.
2. Unit cabinet surface shall be tested 672 hours in salt spray test in compliance with ASTM B117.
3. Cabinet construction shall allow for all service/maintenance from one side of the unit.
4. Cabinet top cover shall be one-piece construction or where seams exist, it shall be double-hemmed and gasket-sealed.
5. Access Panels: Hinged, tool-less access panels shall be provided for the control box, compressors, filters, indoor motor & blower, and the heating section.
6. Insulation: Provide up to 1 inch thick fiberglass insulation with foil face on all exterior panels in contact with the return and conditioned air stream. All edges must be captured so that there is no insulation exposed in the air stream.
7. All unit power wiring shall enter unit cabinet at a single factory provided location and be capable of side or bottom entry to minimize roof penetrations and avoid unit field modifications. Separate side and bottom openings shall be provided for the control wiring.
8. The base of the unit shall have 3 sides for forklift provisions. The base of the units shall have rigging/lifting holes for crane maneuvering.
9. Fan performance measuring ports shall be provided on the outside of the cabinet to allow accurate air measurements of evaporator fan performance without removing panels or creating bypass of the coils.
10. Condensate pan shall be slide out design, constructed of a non-corrosive material, internally sloped and conforming to ASHRAE 62-B9 standards.

C. AIR FILTERS

1. Factory installed filters shall mount integral within the unit and shall be accessible through access panels. Two-inch thick pleated MERV-8 and MERV-13 filters shall be furnished and installed.

D. FANS AND MOTORS

1. Provide evaporator fan section with forward curved, double width, double inlet, centrifugal type fan.
2. Provide self-aligning, grease lubricated, ball or sleeve bearings with permanent lubrication fittings.
3. Entire blower assembly and motor shall be slide out design.
4. Outdoor and Indoor Fan motors shall be permanently lubricate and have internal thermal overload protection.
5. Outdoor fans shall be direct drive, statically and dynamically balanced, draw through in the vertical discharge position.
6. Provide shafts constructed of solid hot rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.

E. EVAPORATOR COIL

1. Evaporator coils shall have aluminum plate fins mechanically bonded to seamless internally enhanced copper tubes with all joints brazed.
2. Evaporator coils shall be of the direct expansion, draw-thru design.
3. Refrigerant Circuit and Refrigerant Safety Components shall include:

    a. Independent fixed-orifice or thermally operated expansion devices.
    b. Solid core filter drier/strainer to eliminate any moisture or foreign matter.
    c. Accessible service gage connections on both suction and discharge lines to charge, evacuate, and measure refrigerant pressure during any necessary servicing or troubleshooting, without losing charge.
    d. The unit shall have two independent refrigerant circuits, equally split in 50% capacity increments.

F. CONDENSER SECTION

1. Condenser coils shall have aluminum plate fins mechanically bonded to seamless internally enhanced copper tubes with all joints brazed or Micro-Channel aluminum tube, aluminum fins.
2. Condenser coils shall be of the draw-thru design.
3. The outdoor fans shall be of the direct drive type, discharge air vertically, have aluminum blades riveted to corrosion resistant steel spider brackets and shall be dynamically balanced for smooth operation. The outdoor fan motors shall have permanently lubricated bearings internally protected against overload conditions and staged independently.
4. Provide factory hail guards.

G. REFRIGERANT SYSTEM

1. Unit shall be factory charged with R-454B refrigerant.
2. Compressors: Shall be fully hermetic type, direct drive, internally protected with internal high-pressure relief and over temperature protection. The hermetic motor shall be suction

gas cooled and have a voltage range of + or – 10% of the unit nameplate voltage. Shall have internal spring isolation and sound muffling to minimize vibration and noise, and be externally isolated on a dedicated, independent mounting.

3. Units shall have cooling capabilities down to 0 degree F as standard.
4. Units shall have heating performance shall be based on 47 degree F outside air temperature at 70% relative humidity.
5. Provide each unit with refrigerant circuits factory-supplied completely piped with liquid line filter-drier, suction and liquid line pressure ports

H. DEHUMIDIFICATION

1. Factory installed and provide dehumidification of an occupied space while maintaining temperature control utilizing a hot gas reheat coil.

    a. Determination of unit functionality in straight cooling, straight heating, or reheat mode shall come from standard control board.
    b. Reheat mode shall utilize a specific reheat coil placed after the evaporator coil to heat the conditioned air back to a neutral temperature when the occupied space requires dehumidification, but the temperature requirements are satisfied.
    c. The reheat circuit shall utilize solenoids to alter the refrigerant flow from being directed through the condenser circuit to the hot gas reheat circuit.
    d. Changeover from cooling mode to reheat mode shall be accomplished in 30 seconds or less.

2.4 POWERED EXHAUST

1. Provide a factory installed power exhaust assembly that shall assist the barometric relief damper in the economizer in relieving building pressurization.
2. Power exhaust shall be controlled by economizer controller operation. Exhaust fans shall be energized when dampers open past the 0- 100% adjustable set point on the economizer control.

2.5 OUTDOOR AIR SECTION

1. Provide a fully integrated 100% modulating outside air economizer with outdoor and return air dampers.

    a. The maximum leakage rate for the outdoor air intake dampers shall be designed to meet ASHRAE 90.1-2010, AMCA 511 Class 1A damper, and the International Energy Conservation Code (IECC) certification requirements by achieving leakage rates of 3 cfm/sq. ft. at 1" of static pressure.
    b. Changeover from compressor to economizer operation shall be provided by an integral electronic enthalpy control that feeds input into the basic module.
    c. Provide ability for simultaneous economizer/compressor operation.
    d. Outside air dampers shall fully close on power loss.

2. The outdoor intake opening shall be covered with a rain hood that matches the exterior of the unit. Water eliminator/filters shall be provided.
3. Provide power exhaust with barometric relief damper.

2.6 CONTROLS

1. Unit shall be complete with self-contained low-voltage control circuit protected by a resettable circuit breaker on the 24-volt transformer side.
2. Unit shall incorporate a lockout circuit which provides reset capability at the space thermostat or base unit, should any of the following standard safety devices trip and shut off compressor:

    a. Loss-of-charge/Low-pressure switch.
    b. High-pressure switch.
    c. Freeze condition sensor on evaporator coil. If any of these safety devices trip, the LCD screen will display the alarm message.

3. Unit shall incorporate "AUTO RESET" compressor over temperature, over current protection.
4. Unit control board shall have on-board diagnostics and fault message display on.
5. Standard controls shall include anti-short cycle and low voltage protection, and permit cooling operation down to a selectable value as low as 0 °F.
6. Control board shall monitor each refrigerant safety switch independently.
7. Microprocessor Control System:

    a. Configured to communicate with multiple BAS communication protocols to integrate with building automation systems. Protocols supported include: BACnet®, MS/TP, Modbus®, and N2 communication
    b. Temperature Sensors: Factory installed supply air, return air, and outdoor air temperature sensors.
    c. On-board USB Port: Provide access to data logging, current and previous system faults and software update capabilities using the on board USB port and common flash drive.
    d. Embedded LCD Display: Include built-in LCD display and easy to use navigation joystick and buttons allowing the user to quickly navigate the menus displaying unit status, options, current function, supply, return and outdoor temperatures, fault codes and other information.
    e. Safety Monitoring: Monitors outdoor, supply, and return air temperatures and the high and low pressure switch status on the independent refrigerant circuits. Monitor gas valve and high temperature limit switches on gas and electric heating units. Monitor the voltage supplied to the unit and will protect the unit if low voltage due to a brown out, or other electrical issue occurs.
    f. Low Ambient: Integrated low-ambient control allows units to operate in the cooling mode down to 0°F outdoor ambient without additional components or intervention. Optionally, the control board can be programmed to lockout the compressors when the outdoor air temperature is low or when free cooling is available.
    g. Anti-Short Cycle Protection: Provide compressor anti-short cycle delay is and programmable minimum run times. Provide temporary override of anti-short cycle delay via push of a button for testing.
    h. Fan Delays: Provide fully programmable independent heating and cooling fan on and fan off delays.
    i. Nuisance Trip Protection and Three Strikes: The high, low-pressure switch, anti-freeze protection, low voltage or heating high limit must trip three times within

two hours before the unit control board will lock out the associated compressor. An alarm message will be displayed on the LCD screen.

j. Lead-Lag: Provide integrated, selectable Lead-Lag option allows equal run time hours on all compressors, thereby extending the life of all compressors.

k. Low Limit Control (LLC): Provide programmable low limit controls to prevent the supply air from dropping below a specified set point when there is a demand for cooling during cold outside conditions.

l. FDD (Fault Detection and Diagnostics): Constantly monitor refrigerant circuit pressures, refrigerant circuit temperatures and environmental temperatures and humidity via multiple sensor inputs.

1) Provide operational characteristics of the rooftop unit entire refrigerant circuit to ensure the unit is functioning at its specified performance level.
2) Provide alarms if the unit is not functioning optimally.
3) Remotely accessible via the Mobile Access Portal (MAP) gateway as well as scrolled on the UCB LCD screen

2.7 VARIABLE FREQUENCY DRIVE

a. Variable Frequency Drive shall be installed inside the unit cabinet, mounted, wired and tested.
b. Shall contain Electromagnetic Interference (EMI) frequency protection.
c. Insulated Gate Bi- Polar Transistors (IGBT) used to produce the output pulse width modulated (PWM) waveform.
d. Built in LED display and controls. Does not require additional kit or options.
e. RS485 capability standard.
f. Electronic thermal overload protection.
g. 5% swinging chokes for harmonic reduction and improved power factor.
h. All printed circuit boards shall be conformal coated.

B. ACCESSORIES- FACTORY INSTALLED

1. Phase Monitor: Provide phase monitor to provide protection against phase reversal, phase loss, and phase unbalance conditions: (RTU-1 thru 3)
2. Power exhaust: Factory installed, powered by unit single point power connection: (RTU-1 thru 3)
3. Low leak economizer, comparative enthalpy: (RTU-1 thru 3)
4. Disconnects, non-fused, unit mounted: (RTU-1 thru 3)
5. Clogged filter and fan failure switches: (RTU-1 thru 3)
6. Hinged access doors: (RTU-1 thru 3)
7. Stainless steel drain pan: (RTU-1 thru 3)
8. Dehumidification, hot gas reheat: (RTU-1 thru 3)
9. Direct drive, plenum type, supply fan with VFD: (RTU-1 thru 3)
10. Duct mounted humidity sensor: (RTU-1 thru 3)
11. Powered Convenience outlet: (RTU-1 thru 3)
12. Clogged filter switch: (RTU-1 thru 3)

C. CAPACITIES AND CHARACTERISTICS

1. Refer to schedule on drawings.

D. ELECTRICAL

1. General Requirements for Electrical:

   a. The air handling unit manufacturer shall factory prewire the fan motors, internal lights and switch, receptacles, where specified, The entire air handling unit as assembled at the factory shall be either UL or ETL labeled.
   b. Type THHN/THWN insulation, rated 600volts.
   c. All wiring shall be in accordance with NEC and the entire unit shall be either ETL or UL Certified.

2. Unit shall utilize factory Through-the-base Electrical with Disconnect Switch.
3. The unit shall have single power connection for 3 phase wiring with factory installed distribution blocks. All wiring shall terminate at a junction box for single point power hit. If a single point power hit is not provided between modular sections, contractor to provide all wiring between junction boxes to make a complete and operable system.
4. The unit shall have unit mounted, non-fusible, NEMA 4X, lockable disconnect switch.
5. The control voltage wiring shall be class 2, 120Vac and/or 24VAC/DC
6. The air handling unit manufacturer shall factory prewire an industrial quality vapor tight marine light fixture in the fan section and with an external switch near the access door and shall prewire a 120V ground fault circuit interrupting convenience receptacle inside the fan section.

2.8 ROOF CURBS

A. Delegated Design: Design roof curbs and associated anchors including comprehensive engineering analysis signed and sealed by a qualified professional engineer, licensed in the project location state, responsible for their preparation. Wind pressures are to be determined by delegated design engineer based on site specific wind criteria indicated below. All building attachments to be coordinated with existing structural conditions.

1. Detail fabrication and assembly of rooftop unit and roof curb.
2. Wind Design Loads:

   a. Basic wind speed: 115 MPH
   b. Exposure Category: C

B. Structural Performance: Equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

C. Materials: Design including all anchoring and fasteners for the Project site location. Construction shall be galvanized steel with corrosion-protection coating, watertight gaskets complying with NRCA standards.

1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.

   a. Materials: ASTM C 1071, Type I or II.
   b. Thickness: 2 inches.

c. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.

1) Liner Adhesive: Comply with ASTM C 916, Type I.
2) Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.

D. Curb Height: 24 inches.

2.9 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

C. All factory-built exhaust units shall be tested in accordance with the latest applicable industry standards as specified herein and be either UL or ETL listed.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Equipment Mounting:

1. Install unit on roof curb. Install wind restraints according to curb manufacturer's written instructions

B. Arrange installation of units to provide access space around air-handling units for service and maintenance.

C. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters

D. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

E. Provide insulation within roof curb and insulate duct through the roof. Refer to drawing details for further information.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Connect duct to unit with a hard duct connection.

C. Duct installation requirements are specified in other HVAC Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:

1. Install ducts to termination at top of roof curb.
2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
3. Install duct continuously through roof structure

D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, section assembly, and to assist in testing.

B. Tests and Inspections:

1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
2. Leak Test: If factory test of unit did not meet leakage rate requirements, unit to be retested in the field after final installation with all sections assembled and sealed to meet required leakage rates.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

D. Remove and replace malfunctioning units and retest as specified above

E. Prepare test and inspection reports.

3.5 START-UP SERVICE

A. Engage a factory-authorized service representative to perform start-up service.

1. Complete installation and start-up checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that dampers open and close.
7. Install new, clean filters.
8. Verify unit assembly is per manufacturer guidelines.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to site during other-than-normal occupancy hours for this purpose.

D. After completing system installation and testing, adjusting, and balancing RTU and air-distribution systems, clean filter housings and install new filters.

3.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing the unit and air-distribution systems and after completing start-up service, clean units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel for a minimum of 2-hours to adjust, operate, and maintain air-handling units.

END OF SECTION 237413